

Applying the BOPPPS-CDIO Instructional Framework in an Information Design Course: A Local Cultural Information Visualization Project

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Abstract

Information design courses require students to integrate information selection, structural organization, visual expression, user understanding, and project implementation. However, traditional design teaching often emphasizes final visual outcomes while giving insufficient attention to information hierarchy, project-process management, and iterative feedback. This study developed and implemented a bridge-in, objective, pre-assessment, participatory learning, post-assessment, summary (BOPPPS) - conceive, design, implement, operate (CDIO) instructional framework in a local cultural information visualization project. A one-group pre-test and post-test mixed-methods design was adopted with 60 second-year undergraduate students in art and design-related programmes over a nine-week course. Data were collected through a perceived learning outcomes questionnaire, individual work evaluation, open-ended responses, and learning reflection texts. The results indicated positive changes in students' perceived learning engagement, understanding of the information design process, project-based learning ability, information organization and visual expression, feedback and reflective learning, and willingness to transfer learning. The final works also showed stronger performance in information hierarchy, visual clarity, and design completeness. Qualitative findings further suggested that students shifted from visual decoration to information logic, from passive task completion to active project development, and from one-time submission to feedback-based revision. The findings provide preliminary evidence for a structured, project-based, and feedback-driven approach to information visualization learning in design education.

Keywords

Information design education, Information visualization, Project-based learning, Design education

Introduction

Background and problem statement

Information design is an important course in art and design programmes because it connects visual communication, information organization, user understanding, and design expression. Unlike general visual expression courses, information design requires students to build practical capabilities covering graphics, layout, colour and visual style. It also trains them to extract core information from complicated resources, set up information hierarchies, design smooth reading routes and convert data into targeted visual content for designated readers and communication scenarios. Visualization research suggests that the value of visual representation lies not only in producing images but also in helping readers identify, understand, and remember complex information [1]. Therefore, the teaching focus

of information design should move beyond visual embellishment and further emphasize information logic, user orientation, and communicative effectiveness.

In traditional art and design courses, teaching is often organized around teacher explanation, case demonstration, student assignments, and teacher critique. This approach is useful for transmitting basic knowledge and supporting case-based understanding, but it may also lead to several teaching problems. First, students may interpret course tasks mainly as the production of final visual outcomes, while paying insufficient attention to problem definition, material selection, and information structure. Second, staged feedback during the course process may be insufficient, causing students to revise their work only near the end of the course and limiting meaningful design iteration. Third, assessment may

overemphasize final visual effects while giving less attention to project process, user analysis, information hierarchy, and learning reflection. Constructive alignment theory emphasizes that learning objectives, teaching activities, and assessment should be aligned with intended learning outcomes [2]. From this perspective, information design courses should not rely only on final works for assessment. Instead, material collection, information classification, visual exploration, feedback-based revision, and learning reflection should be integrated into the course process.

A local cultural information visualization project further intensifies these teaching challenges. Local cultural materials often include historical, geographical, social, craft-based, visual, and contemporary communication elements. Without sufficient skills in information selection and structural organization, students' works may become compilations of cultural materials, decorative combinations of traditional patterns, or superficial uses of visual symbols. Such outcomes may fail to develop clear user orientation or communication value. Therefore, information design courses require a clearer instructional structure that enables students to move from understanding cultural materials to translating information visually through explicit objectives, staged project development, continuous feedback, and reflective learning.

Research gap

Previous studies have discussed higher education teaching reform from the perspectives of project-based learning, formative assessment, peer assessment, feedback literacy, the BOPPPS instructional model, and the CDIO project process. Project-based learning emphasizes sustained inquiry around authentic problems and supports the development of knowledge application and problem-solving abilities [3]. Formative feedback helps students understand the gap between their current performance and learning goals and further adjust their learning strategies [4]. Peer assessment also helps students understand quality criteria by evaluating others' work and reflecting on their own work [5]. In addition, feedback literacy research suggests that students' uptake of feedback depends on their ability to understand feedback, make judgments, and transform feedback into improvement actions [6].

BOPPPS is a structured classroom teaching model that

helps teachers organize bridge-in activities, learning objectives, pre-assessment, participatory learning, post-assessment, and summary. Prior studies have suggested that BOPPPS, especially when combined with outcome-based education, may support student engagement, learning performance, and classroom organization [7,8]. CDIO, by contrast, emphasizes the project process of conceiving, designing, implementing, and operating, and is commonly used to support practice-oriented and competence-oriented curriculum reform [9].

Nevertheless, three gaps remain. First, many studies on BOPPPS or CDIO have been conducted in medical education, engineering education, and general classroom settings, while relatively limited attention has been given to art and design courses, particularly information design courses. Second, BOPPPS and CDIO are often discussed separately, and fewer studies have integrated them as a dual framework consisting of a classroom structure and a project process. Third, some course reform studies remain at the level of teaching experience reports and lack multiple sources of evidence, such as pretest-posttest questionnaires, work evaluation rubrics, open-ended responses, and learning reflection texts. It is therefore necessary to develop and evaluate a BOPPPS-CDIO instructional framework for information design courses in an authentic course setting.

Research aims and contributions

This study aimed to develop and implement a BOPPPS-CDIO instructional framework for an information design course and to evaluate its instructional value through quantitative and qualitative data. A local cultural information visualization project was used as the course task, guiding students through problem identification, material collection, information classification, visual ideation, prototype development, feedback-based revision, final presentation, and learning reflection.

This study makes three main contributions. First, it proposes a structured instructional framework that aligns BOPPPS classroom stages with CDIO project phases to address the tendency of traditional design courses to emphasize final outcomes while underemphasizing the learning process. Second, it uses multiple sources of evidence, including students' self-reported questionnaires, individual work evaluation, open-ended responses, and learning reflection texts, to examine students' perceived learning outcomes, project

performance, and learning experiences. Third, it extends the integration of BOPPPS and CDIO to information visualization learning in design education, providing empirical reference for information design course reform and local cultural visual communication teaching.

Literature review

Information design education and information visualization learning

The core aim of an information design course is not simply to produce visual images, but to support audience understanding of complex information through visual structures. Students need to learn how to identify information sources, select key content, establish information hierarchy, organize reading paths, and transform complex materials into clear, readable, and purposeful visual communication. Information visualization learning requires students to translate data, cultural materials, narrative content, or knowledge structures into visual forms that support understanding [10]. Therefore, the quality of student work should not be evaluated only by visual style, but also by whether the information hierarchy is clear, the visual path is coherent, the target users are defined, and the content is readable and communicatively effective.

In local cultural themes, students also need to avoid reducing cultural design to the use of symbolic motifs or decorative patterns. Instead, they should present the logical relationships among cultural contents through information selection and structural organization. In this sense, information design courses require a more explicit instructional structure that helps students understand the transformation process from materials to structures, from structures to visual forms, and from visual forms to communication.

Project-based learning, feedback, and reflective learning

Project-based learning emphasizes sustained inquiry around authentic or near-authentic problems and supports the development of knowledge application, problem-solving, and self-directed learning abilities. Information design work is usually not a one-time visual assignment, but a process-based outcome involving problem definition, material analysis, structural construction, visual expression, and feedback-based revision. Therefore, project-based learning is highly relevant to information design courses. Active learning

research also suggests that students tend to perform better when they take more active roles through discussion, practice, and problem solving [11].

In design education, students need not only to learn how to complete a design work, but also to understand the key judgments involved in the design process and make implicit design thinking discussable, assessable, and revisable [12]. For information design courses, this means that teachers should not evaluate only whether a visual outcome is aesthetically pleasing. They should also help students recognize how information is selected, classified, organized, and translated. Only when the relationships among information structure, user goals, and visual expression are made explicit can students understand the learning aims of information design.

Formative assessment and peer assessment play important roles in this process. Feedback helps students understand the gap between their current performance and learning goals and further adjust their learning strategies [13]. Peer assessment enables students to understand quality criteria by evaluating others' work and reflecting on their own work [14]. In information design courses, effective feedback should not only point out visual-form issues, but also address information hierarchy, reading sequence, user orientation, visual clarity, and communication goals. Whether students can make effective use of feedback also depends on their feedback literacy, namely their ability to understand feedback, make judgments, and transform feedback into improvement actions.

Reflective learning helps students transform their experience in a course project into transferable methods. Through learning reflection, students can review how they understood local cultural materials, selected and classified information, revised their work based on feedback, and considered how information visualization methods could be applied to other design courses or authentic projects. Therefore, this study regards project-based learning, active learning, formative feedback, peer assessment, and reflective learning as important theoretical foundations for the instructional intervention.

BOPPPS as a classroom structure

BOPPPS is a structured classroom teaching model consisting of six stages: bridge-in, objective, pre-assessment, participatory learning, post-assessment, and summary. Bridge-in is used to establish the learning

context and problem awareness. Objective clarifies learning aims and assessment requirements. Pre-assessment diagnoses students' prior knowledge and learning foundations. Participatory learning organizes classroom interaction, case analysis, discussion, and practice. Post-assessment examines learning outcomes, while Summary consolidates knowledge structures and guides reflection and transfer. Previous studies have suggested that BOPPPS may have positive effects on student participation, classroom organization, and learning performance.

For information design courses, the value of BOPPPS lies in shifting classroom teaching from one-way instruction to goal-oriented, process-controlled, and feedback-supported learning organization. Through the Bridge-in stage, teachers can introduce students to authentic local cultural communication problems. Through the objective stage, students can understand that the course task includes not only final visual work, but also material collection, information classification, sketch exploration, staged feedback, and learning reflection. Through pre-assessment, teachers can identify differences in students' information design foundations, project-based learning experience, and visual expression ability. Through participatory learning, students can gradually develop their projects through case analysis, peer discussion, teacher feedback, and work revision. However, BOPPPS mainly addresses how classroom learning events are organized. It helps teachers arrange introduction, objectives, interaction, assessment, and summary, but does not fully explain how students move from project conception to design implementation and final presentation. For project-based courses such as information design, classroom structure alone is insufficient. A practical framework that describes the project development process is also needed.

CDIO as a project process

CDIO originated from engineering education reform. Its core stages include conceive, design, implement, and operate, emphasizing that students should experience a complete project process from conception to implementation and operation. As a systematic curriculum reform framework, CDIO emphasizes the integration of curriculum objectives, competence development, and practical projects. Although CDIO was originally developed mainly for engineering education,

its project-based, process-oriented, and practice-oriented features are also relevant to design education. Art and design courses similarly require students to move from problem identification to user analysis, solution development, prototype production, feedback-based revision, and final presentation.

In an information design course, the conceive stage can correspond to identifying local cultural communication problems, defining the project theme, and analysing target users and communication contexts. The design stage can correspond to material selection, information classification, information hierarchy construction, and visual solution development. The implement stage can correspond to sketching, prototyping, layout design, visual refinement, and final work completion. In this course context, the operate stage mainly refers to work presentation, assessment feedback, and methodological transfer, rather than strict product operation or external user validation. In this way, CDIO can help transform a course task from a single assignment into a relatively complete project-based learning process.

However, CDIO mainly describes the logic of project progression. It does not directly specify how each class should be introduced, how students' prior knowledge should be diagnosed, how participation should be organized, or how staged assessment and summary should be conducted. Therefore, in an information design course, CDIO needs to be combined with a more specific classroom teaching structure in order to form an instructional framework that includes both a project process and a classroom implementation pathway.

Integrating BOPPPS-CDIO for local cultural information visualization learning

The BOPPPS-CDIO integration in this study is not a simple combination of two teaching models. BOPPPS is mainly used to organize classroom learning events, addressing how the class is introduced, how objectives are clarified, how participatory learning is organized, and how assessment and summary are conducted. CDIO is mainly used to organize the project development process, addressing how students move from problem conception to solution design, work implementation, final presentation, and reflection. When these two models are aligned, students can understand information design as a staged, reflective, and feedback-driven learning process. The local cultural information visualization project

provides an appropriate task carrier for this integrated framework. Local cultural materials are complex, contextual, and visually identifiable, encouraging students to engage with authentic problems of information selection and structural organization. Students need to extract key content from substantial cultural materials, identify logical relationships among information elements, construct information hierarchies suitable for target users, and complete visual translation through graphics, layout, colour, text, and prototype development. Therefore, local cultural information visualization is not only a course theme, but also a pedagogical context for developing students' information organization, user understanding, and visual communication abilities. Based on the above theoretical foundation, this study embedded the BOPPPS classroom stages into the CDIO project process to form a structured instructional framework for an information design course. The framework addresses both how teachers organize

classroom learning and how students develop individual projects. It also connects knowledge understanding with work iteration, and final outcomes with process materials and learning reflection.

To further illustrate the instructional logic of this study, Figure 1 presents the relationship among the BOPPPS classroom structure, the CDIO project process, the local cultural information visualization design project, and the expected learning changes. The framework begins with the main teaching problems in the information design course. It uses BOPPPS to organize classroom learning events, CDIO to structure project development, and the local cultural information visualization project as the task carrier. It ultimately aims to support improvements in students' learning engagement, understanding of the information design process, project-based learning ability, information organization and visual expression, feedback use and reflective learning, and cultural information translation.

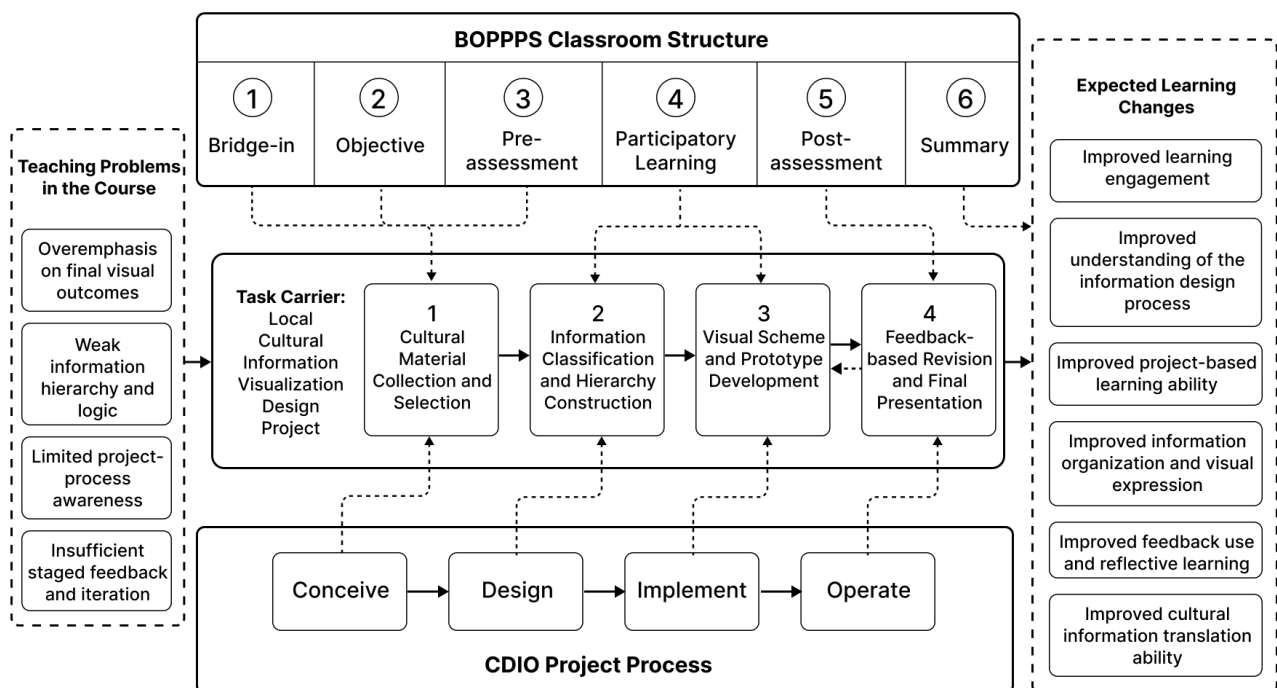


Figure 1. Conceptual framework of BOPPPS-CDIO supported local cultural information visualization learning.

Figure 1 indicates that the instructional framework does not simply place BOPPPS and CDIO side by side. Instead, it aligns classroom structure with project progression through their functional division. The six BOPPPS stages mainly address how to introduce learning, clarify objectives, diagnose prior knowledge, organize participation, assess learning, and guide summary and reflection. The four CDIO stages mainly address how students move from cultural information problem

identification to information structure construction, visual solution development, feedback-based revision, final presentation, and reflective transfer. The local cultural information visualization project functions as the task carrier that links course problems, instructional processes, and expected learning changes.

Research questions

Based on the research background and gaps discussed above, this study addressed the following research

questions:

RQ1: How was the BOPPPS-CDIO instructional framework designed and implemented in an information design course?

RQ2: How did the instructional intervention affect students' perceived learning outcomes?

RQ3: How did students' individual information visualization project performance change during the course?

RQ4: How did students understand the learning process, feedback use, and course improvement in this instructional model?

Methods

Research design

This study adopted a one-group pre-test and post-test mixed-methods design in a real course setting. Because the course was implemented within an existing class arrangement, teaching schedule, and institutional course structure, the study was not designed as a randomized controlled experiment. Instead, it was positioned as a classroom-based instructional intervention. Multiple sources of evidence were used to examine students' perceived learning outcomes, individual project performance, and reflective understanding.

Specifically, the BOPPPS-CDIO instructional framework served as the instructional intervention, while the local cultural information visualization project served as the course task. Quantitative data included the pretest and post-test perceived learning outcomes questionnaire and the scores of individual draft and final works. Qualitative data included open-ended responses and learning reflection texts. Through the convergence of questionnaire data, work evaluation, and qualitative texts, the study aimed to examine students' learning changes during the course more comprehensively.

The one-group pre-test and post-test design was used

because the study was embedded in an authentic teaching context, where course enrolment, teaching duration, and class organization made it difficult to establish a strictly randomized control group. Therefore, the findings were not interpreted as strong causal evidence. Instead, the study was treated as a course-based instructional intervention study. To reduce the limitation of relying on a single data source, students' self-reported questionnaire data, work evaluation, and open-ended feedback were collected to form a multi-source evidence chain.

Participants and course context

The participants were 60 students enrolled in an information design course in the School of Design at Guangzhou Nanfang College. All participants were second-year undergraduate students from art and design-related programmes, including art design, digital media art, digital media technology, and public art. Among them, 32 students were from art design, accounting for 53.3%; 14 were from digital media art, accounting for 23.3%; 8 were from digital media technology, accounting for 13.3%; and 6 were from public art, accounting for 10.0%. In terms of gender, 18 students were male, accounting for 30.0%, and 42 were female, accounting for 70.0%.

Regarding prior learning experience, 9 students had systematically studied information design-related courses, accounting for 15.0%, while 28 students had participated in project-based design courses or design competitions, accounting for 46.7%. All 60 students completed of pre-test, post-test questionnaire, and final individual course work required for the study, and were therefore included in the subsequent analysis. Because all participants came from the same year level, course cycle, and course task context, the study could examine learning changes within a relatively consistent teaching environment.

Table 1. Participant characteristics.

Variable	Category	n	%
Total sample	Valid sample	60	100.0
Gender	Male	18	30.0
	Female	42	70.0
Year level	Second year	60	100.0
Programme	Art design	32	53.3
	Digital media art	14	23.3
	Digital media technology	8	13.3
	Public art	6	10.0
Prior systematic study of information design-related courses	Yes	9	15.0
	No	51	85.0

Variable	Category	n	%
Prior participation in project-based design courses or design competitions	Yes	28	46.7
	No	32	53.3
Completion of pretest and posttest questionnaires	Yes	60	100.0
Submission of final individual course work	Yes	60	100.0

Note: percentages may not sum to 100.0% due to rounding.

Instructional intervention: The BOPPPS-CDIO instructional framework

The instructional intervention integrated the BOPPPS classroom teaching structure with the CDIO project process to form a structured project-based instructional framework for the information design course. The course used a local cultural information visualization project as an individual project task. Each student was required to select a local cultural topic and complete material collection, information classification, hierarchy construction, visual sketching, prototype design, staged feedback, work revision, and final presentation. The project was not treated as a general cultural poster design task. Instead, students were expected to transform complex local cultural materials into an information visualization work with a clear information structure, explicit user orientation, and effective visual communication.

The six BOPPPS stages were used to organize the classroom teaching rhythm. In the bridge-in stage, authentic cases of local cultural information communication were introduced to establish a problem context. In the objective stage, the project task, assessment criteria, and staged outputs were clarified. In

the pre-assessment stage, students' initial differences in information design foundations and project-based learning ability were identified. In the participatory learning stage, case analysis, group discussion, peer assessment, and teacher feedback were organized to support students' transition from material analysis to project prototyping. In the post-assessment stage, students' final works and learning outcomes were assessed. In the summary stage, students were guided to conduct learning reflection and methodological transfer. The four CDIO stages were used to organize project progression. In the conceive stage, students identified problems in local cultural information communication and clarified the project theme, target users, and communication context. In the design stage, students completed material selection, information classification, information hierarchy construction, and visual solution development. In the implement stage, students transformed information structures into individual sketches, prototypes, and final visualization works. In the operate stage, students presented their works, received evaluation, and reflected on the transfer value of the design method for other courses or authentic projects (Table 2).

Table 2. Alignment between BOPPPS classroom stages and CDIO project phases.

BOPPPS stage	CDIO phase	Course activity	Student output	Evidence collected
Bridge-in	Conceive	Case analysis of local cultural communication and problem-context introduction	Initial topic awareness and problem understanding	Classroom observation notes and initial reflection materials
Objective	Conceive	Explanation of project task, learning objectives, and evaluation rubric	Understanding of project direction and evaluation criteria	Project brief, rubric explanation, and process materials
Pre-assessment	Conceive / Design	Pretest questionnaire and diagnosis of prior foundations	Pre-course learning profile	Pretest questionnaire
Participatory Learning	Design / Implement	Material collection, information classification, sketch exploration, prototype development, peer assessment, and teacher feedback	Individual draft and process work	Draft scores, peer assessment records, and teacher feedback records
Post-assessment	Implement / Operate	Final submission, post-test questionnaire, and course evaluation	Individual final work	Post-test questionnaire, final work scores, and final works

BOPPPS stage	CDIO phase	Course activity	Student output	Evidence collected
Summary	Operate	Work presentation, learning reflection, and transfer discussion	Learning reflection texts	Open-ended responses and learning reflection texts

Research instruments

This study used a self-developed perceived learning outcomes questionnaire to examine students' learning changes before and after the instructional intervention. The questionnaire was developed based on the course objectives, the BOPPPS-CDIO instructional structure, and the intended learning outcomes of the information design course. It used a five-point Likert scale, where 1 indicated strongly disagree and 5 indicated strongly agree. Before formal use, two teachers with experience in design education reviewed the questionnaire items. They mainly examined the alignment between the items and the course objectives, the coverage of key learning stages in the BOPPPS-CDIO framework, and the clarity of item wording. Based on their review, several items were revised for clarity and relevance.

The final questionnaire included six dimensions with 30 scale items. The six dimensions were learning engagement, understanding of the information design process, project-based learning ability, information organization and visual expression ability, collaborative feedback and reflective learning, and learning satisfaction and transfer intention. Each dimension contained five items. The items addressed whether students could understand course objectives, identify information hierarchy, organize cultural materials, manage project development, use feedback to revise their work, and transfer information visualization methods to other design tasks. In addition to the scale items, the questionnaire included four open-ended questions, which asked students about the most helpful instructional activities, major project difficulties, the influence of feedback on work revision, and suggestions for course improvement.

To avoid relying solely on students' self-reported data, this study used a work evaluation rubric to assess students' individual information visualization works. The rubric contained five dimensions: information hierarchy, user orientation, visual clarity, visual expression, and design completeness. Each dimension was scored from 1 to 5, resulting in a total score of 25.

The same rubric was used to assess both the draft and final work, ensuring comparability between the two stages. The work evaluation was conducted by the course teacher based on the unified rubric. The limited number of raters may have introduced potential rater bias, which is further acknowledged in the limitations section.

Open-ended responses and learning reflection texts were used to explain the learning mechanisms behind the quantitative results. The open-ended questions focused on the most helpful instructional activities, major difficulties during project development, the influence of classroom discussion or feedback on work revision, and suggestions for course improvement. The learning reflection texts required students to summarize their understanding of local culture, information selection, information classification, information hierarchy construction, work revision, and methodological transfer.

Data collection procedure

Data were collected throughout the nine-week course. In Week 1, the course was introduced, the project task was explained, cases were analysed, and the pretest questionnaire was administered. In Weeks 2-3, students selected local cultural topics, collected materials, conducted target user analysis, and completed information classification. In Weeks 4-5, students developed information hierarchy diagrams, sketch proposals, and initial prototypes. In Weeks 6-7, students participated in interim presentations, received peer assessment and teacher feedback, and submitted individual draft materials for scoring. In Weeks 8-9, students revised their works based on feedback and completed the final information visualization work, posttest questionnaire, open-ended responses, and learning reflection texts.

The pretest and posttest were completed by the same group of students. The questionnaires were collected anonymously and matched through student codes. Both draft and final works were assessed using the same work evaluation rubric. Because the course works were completed individually, work scores were analysed at the individual level. The draft and final scores of the 60

students were paired using student codes. Open-ended responses and learning reflection texts were collected at the end of the course and anonymized before qualitative analysis.

To further illustrate the relationship among course implementation, data sources, analysis methods, and research outputs, Figure 2 presents the nine-week course

implementation and data collection process. The figure integrates instructional stages, data collection tools, analysis methods, and the evidence chain, showing how questionnaire data, individual work evaluation, and qualitative texts were used to examine the implementation of the BOPPPS-CDIO instructional framework.

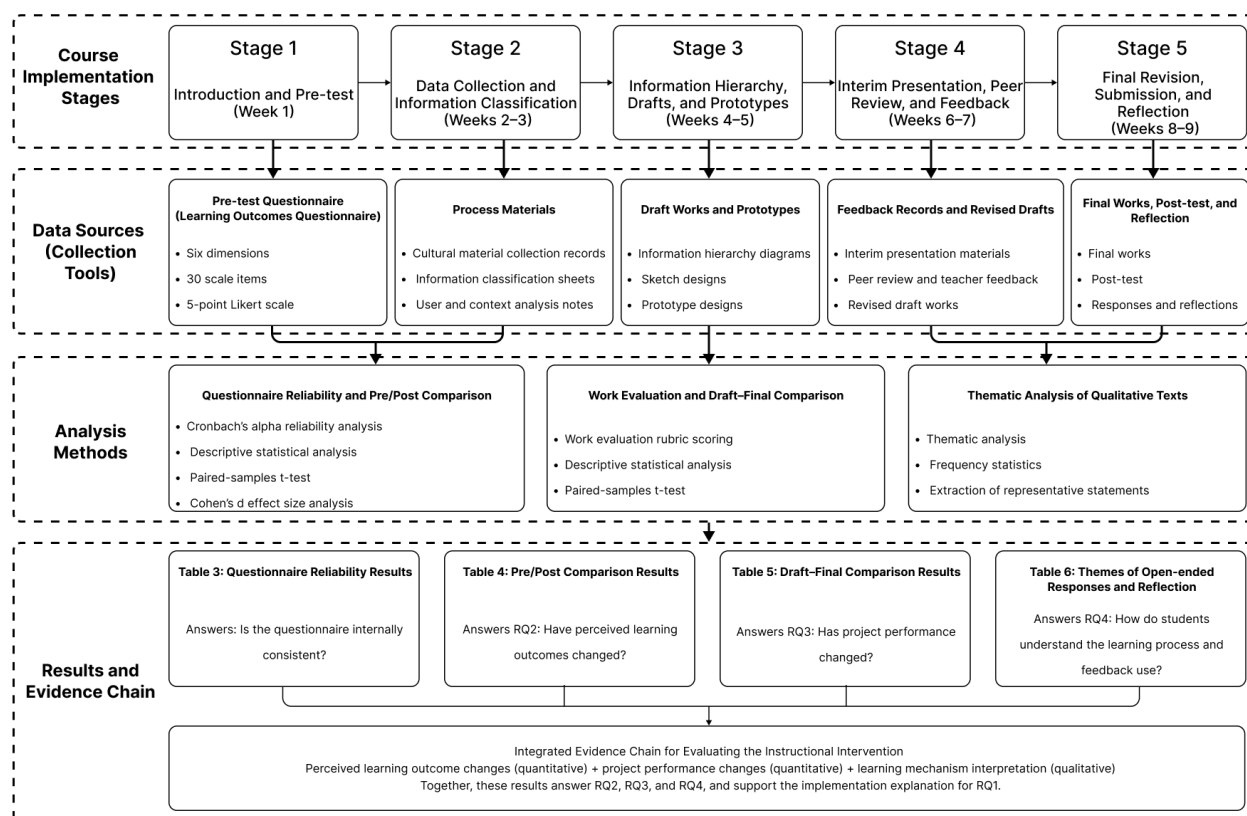


Figure 2. Nine-week course implementation and data collection process.

Figure 2 shows that data collection was synchronized with course progression. The pretest questionnaire was used to analyse students' perceived learning outcomes before the instructional intervention. Process materials, sketch prototypes, and draft works were used to document students' project development. Final works and the post-test questionnaire were used to compare learning changes after the course, while open-ended responses and learning reflection texts were used to interpret the learning mechanisms behind the quantitative results. In this way, questionnaire reliability analysis, pre-test and post-test comparison, draft-final comparison, and thematic analysis jointly formed the evidence chain for evaluating the instructional intervention.

Data analysis

The quantitative data included questionnaire data and individual work scores. First, descriptive statistics were

used to analyse the means and standard deviations of the pretest, post-test, draft work, and final work. Second, Cronbach's α was used to examine the internal consistency of each questionnaire dimension and the overall scale. Cronbach's α is commonly used to assess the internal consistency of multi-item scales. Third, because the same students completed the pretest and post-test and submitted both draft and final works, paired-samples t-tests were used to compare changes in perceived learning outcomes before and after the course, as well as changes in work scores from draft to final work. Cohen's d was also reported to indicate the practical magnitude of the changes.

The qualitative data included open-ended responses and learning reflection texts, which were analysed using thematic analysis. Thematic analysis is suitable for identifying repeated patterns of meaning in textual data.

The analysis involved three steps [15]. First, the open-ended responses and reflection texts were read repeatedly to identify meaning units related to the learning process, information logic, project development, feedback-based revision, and cultural information translation. Second, similar meaning units were grouped into themes, such as shifting from visual decoration to information logic, moving from passive assignment completion to active project development, and changing from one-time submission to feedback-based revision. Third, the frequency of each theme was calculated, and representative anonymized statements were selected to illustrate the themes. All representative statements were anonymized before use.

Ethical considerations

The study data were derived from anonymous questionnaires, work evaluation, open-ended responses, and learning reflection texts collected during the course. Before completing the questionnaire, students were informed of the research purpose, data use, and anonymity principles. Participation in the questionnaire and open-ended responses was voluntary, and refusal to allow relevant data to be used for research did not affect

course grades. Student works and textual materials used in the study were anonymized by removing names, student numbers, and other identifiable information.

Because the study was conducted in a real course context, course assessment and research analysis were separated as far as possible to reduce any potential pressure arising directly from the teacher-student relationship. Questionnaire data were matched using anonymous student codes, and no identifiable personal information was ever reported in the published results. Open-ended responses and learning reflection texts were used only for internal teaching research analysis and were not used to publicly identify individual student performance.

Results

Reliability of the questionnaire

Because this study used a self-developed perceived learning outcomes questionnaire, the internal consistency of the scale was first examined. As shown in Table 3, the Cronbach's α values for all dimensions were acceptable to good, and the overall scale showed high reliability, indicating that the questionnaire was suitable for subsequent mean comparison.

Table 3. Dimensions and reliability of the perceived learning outcomes questionnaire.

Dimension	Item code	Number of items	N	Cronbach's α
Learning engagement	A1-A5	5	60	0.84
Understanding of the information design process	B1-B5	5	60	0.87
Project-based learning ability	C1-C5	5	60	0.85
Information organization and visual expression ability	D1-D5	5	60	0.86
Collaborative feedback and reflective learning	E1-E5	5	60	0.82
Learning satisfaction and transfer intention	F1-F5	5	60	0.88
Overall scale	A1-F5	30	60	0.94

As shown in Table 3, the Cronbach's α values for the six dimensions ranged from 0.82 to 0.88, and the alpha value for the overall scale was 0.94. These results indicate that the questionnaire had good internal consistency and could be used for subsequent comparison of perceived learning outcomes.

Pre-test and post-test comparison of perceived learning outcomes

Table 4 addresses RQ₂ by comparing students' perceived

learning outcomes across six dimensions before and after the course.

The results show that all post-test mean scores were higher than the corresponding pretest mean scores. The largest increase was observed in understanding of the information design process, suggesting that the intervention may have supported students' understanding of the information design process, information hierarchy construction, and project progression.

Table 4. Pre-test and post-test comparison of perceived learning outcomes.

Dimension	Pre-test M	Pre-test SD	Post-test M	Post-test SD	Mean difference	t	p	Cohen's d
Learning engagement	3.11	0.47	4.16	0.42	1.05	12.38	<0.001	1.60
Understanding of the information design process	2.89	0.52	4.12	0.40	1.23	14.06	<0.001	1.81

Dimension	Pre-test M	Pre-test SD	Post-test M	Post-test SD	Mean difference	t	p	Cohen's d
Project-based learning ability	2.96	0.50	4.08	0.43	1.12	12.91	<0.001	1.67
Information organization and visual expression ability	3.02	0.49	4.09	0.41	1.07	12.17	<0.001	1.57
Collaborative feedback and reflective learning	3.18	0.46	4.21	0.39	1.03	11.84	<0.001	1.53
Learning satisfaction and transfer intention	3.09	0.51	4.24	0.38	1.15	13.45	<0.001	1.74
Overall perceived learning outcomes	3.04	0.43	4.15	0.35	1.11	15.22	<0.001	1.97

Table 4 indicates that students reported higher scores in all six learning dimensions after the course. Among these dimensions, understanding of the information design process and learning satisfaction and transfer intention showed relatively large increases. These results suggest that the BOPPPS-CDIO instructional framework may have supported students' understanding of the process-oriented nature of information design and their willingness to transfer related methods to other design tasks.

However, these results should be interpreted as changes in students' perceived learning outcomes rather than

direct evidence of improvement in all aspects of objective learning ability.

Changes in individual information visualization project performance

Table 5 addresses RQ₃ by presenting changes in students' individual project performance from draft to final work. Compared with reporting only final scores, comparing draft and final works better reflects the role of staged feedback, peer assessment, and teacher guidance in work iteration. The same work evaluation rubric was used for both draft and final works, ensuring comparability between the two stages.

Table 5. Comparison of draft and final scores for individual information visualization works.

Evaluation dimension	Draft M	Draft SD	Final M	Final SD	Mean difference	t	p	Cohen's d
Information hierarchy	3.08	0.61	4.18	0.49	1.10	11.26	<0.001	1.45
User orientation	3.15	0.58	4.06	0.53	0.91	9.34	<0.001	1.21
Visual clarity	3.21	0.63	4.22	0.46	1.01	10.87	<0.001	1.40
Visual expression	3.36	0.57	4.13	0.51	0.77	8.12	<0.001	1.05
Design completeness	3.04	0.66	4.27	0.44	1.23	12.48	<0.001	1.61
Total score	15.84	2.64	20.86	1.92	5.02	13.05	<0.001	1.68

Table 5 shows positive changes in all five evaluation dimensions: information hierarchy, user orientation, visual clarity, visual expression, and design completeness. The most notable changes were observed in design completeness, information hierarchy, and visual clarity. This suggests that students' work improved mainly in project completeness, information structure, and readability, rather than only in visual style. This pattern reflects the instructional focus on staged tasks, feedback-based revision, and project progression.

Thematic analysis of open-ended responses and learning reflections

Table 6 addresses RQ₄ by using students' open-ended responses and learning reflection texts to explain the learning mechanisms behind the quantitative findings. The theme distribution shows that students most frequently mentioned feedback-based revision and the shift toward information logic, suggesting that the course influenced not only scores but also students' understanding of the design process.

Table 6. Thematic analysis of open-ended responses and learning reflection texts.

Theme	Number of Students (n)	Percentage (%)	Main meaning	Representative statement
From visual decoration to information logic	43	71.7	Students began to move from focusing on visual appearance to considering information selection, classification, hierarchy, and reading paths.	S01: "Previously, I paid more attention to visual effects in design. This project made me first think about how information should be classified and presented."
From passive assignment completion to active project development	39	65.0	Students felt that staged tasks helped them understand what needed to be completed at each step, making project development more planned.	S08: "Each stage had a clear task. I knew that this week I needed to organize materials and that next week I needed to complete the information structure, instead of just waiting until the final submission."
From one-time submission to feedback-based revision	48	80.0	Students commonly reported that peer assessment and teacher feedback helped them identify problems and revise their individual work continuously.	S15: "My classmates pointed out that the reading order was unclear, and the teacher also suggested reorganizing the modules, so the final version was much clearer than the draft."
From cultural material compilation to cultural information translation	36	60.0	Students began to realize that local cultural design should not simply copy materials or use traditional patterns, but should extract key cultural information and translate it into understandable visual structures.	S22: "At first, I only placed local cultural materials into the work. Later, I realized that I needed to turn cultural content into an infographic that users could understand."
From course task to methodological transfer	34	56.7	Students believed that information classification, user analysis, staged feedback, and visualization methods could be transferred to other design courses or future projects.	S31: "This process can also be used in future poster design, interface design, or cultural communication projects."
Suggestions for course improvement	29	48.3	Students hoped to have more excellent cases, user testing, in-class revision time, and local cultural research activities.	S40: "I hope more real cases can be added in the future, and a user test can also be arranged to see whether others can understand our works."

These themes formed a complementary explanation for the pre-test and post-test and work evaluation results. The first five themes mainly reflect students' learning changes in information logic, project development, feedback use, cultural information translation, and methodological transfer. The final theme reflects students' suggestions for future course improvement.

Discussion

The role of structured classroom organization and project-based progression

The results showed positive changes in students' learning

engagement, understanding of the information design process, and project-based learning ability. These findings suggest that combining structured classroom organization with a project-based design process may help address several common issues in traditional design courses, such as unclear learning objectives, weak connections among classroom tasks, and loosely organized project development. This result is broadly consistent with project-based learning research, which emphasizes authentic tasks, sustained inquiry, and students' increased responsibility for learning.

In this study, BOPPPS mainly functioned as a structure

for organizing classroom learning events. The bridge-in stage introduced authentic local cultural communication cases and helped students recognize that information design was not merely a form of visual decoration, but a design activity oriented toward user understanding and information communication. The Objective stage clarified the project task and evaluation criteria, helping students understand that the course outcomes included not only final visual works, but also process-based materials such as material collection, information classification, sketch exploration, feedback-based revision, and learning reflection. The Pre-assessment, Participatory Learning, Post-assessment, and Summary stages further strengthened the staged and feedback-supported nature of the course. Previous studies have also suggested that structured classroom organization through BOPPPS can support student participation and learning performance and the present study extends this application to an information design course context.

CDIO mainly functioned as a structure for organizing project progression. The Conceive stage guided students to clarify cultural objects, communication problems, and target users. The Design stage required students to complete material selection, information classification, and information hierarchy construction. The Implement stage supported the transformation of information structures into sketches, prototypes, and visual works. The Operate stage involved presentation, evaluation, and reflection for learning transfer. By combining BOPPPS and CDIO, the course provided both a clear classroom rhythm and a relatively complete project process. This dual structure may partly explain the positive changes in students' understanding of the information design process.

Feedback-based iteration and improvement in information visualization quality

The comparison between draft and final work scores showed positive changes in information hierarchy, user orientation, visual clarity, visual expression, and design completeness. The most notable changes appeared in design completeness, information hierarchy, and visual clarity. These findings suggest that peer assessment and teacher feedback played an important role in supporting work iteration. This result aligns with formative feedback research, which emphasizes the learning process of recognizing performance gaps, adjusting strategies, and

taking improvement actions. It is also consistent with feedback literacy research, which highlights students' ability to understand and use feedback for improvement. In information design courses, feedback should not be limited to visual-form issues. More importantly, it should help students reconsider information logic and user understanding. At the draft stage, many students tended to include too much information, present unclear module hierarchies, use visual elements that interfered with reading, or treat cultural symbols superficially. Through peer assessment, students could identify reading-path problems and comprehension barriers from the viewer's perspective. Through teacher feedback, they could further clarify primary and secondary information, optimize visual hierarchy, and adjust design strategies. Therefore, work revision was not merely visual refinement, but an iterative process oriented toward information communication effectiveness.

The open-ended responses and reflection texts supported this interpretation. Feedback-based revision was the most frequently mentioned theme, with 80.0% of students referring to the role of peer assessment or teacher feedback in improving their work. This suggests that feedback affected not only final work quality, but also students' understanding of the design process. Students began to recognize that revising an information design work involved continuous improvement of communication effectiveness based on target users, reading sequence, and information hierarchy.

Local cultural information visualization as a pedagogical carrier

The course task in this study was a local cultural information visualization project. The qualitative results showed that 60.0% of students mentioned a shift from compiling local cultural materials to translating cultural information. This suggests that the instructional intervention was associated not only with classroom participation and project development, but also with changes in how students understood the design object. Local cultural themes are visually attractive, but they may also lead students to remain at the level of symbolic borrowing or decorative expression. For example, when working with local customs, intangible cultural heritage, urban districts, or traditional crafts, students may tend to use traditional patterns, local architectural images, or cultural labels directly, while neglecting the logical

relationships among cultural information. The core task of an information design course is not simply to represent local culture, but to transform complex cultural content into structured information that target users can understand. Design education research emphasizes that key judgments in the design process should be made explicit so that students can understand the methods and reasoning behind design decisions. In this study, the local cultural information visualization project helped students gradually understand the relationship between cultural design and information communication through material selection, information classification, and visual translation.

From a pedagogical perspective, local cultural information visualization is not only a project theme, but also a task carrier for developing students' information organization ability. Local cultural materials are often complex, contextual, and multi-layered, requiring students to engage in material selection, information classification, hierarchy construction, user understanding, and visual translation. Because the task was complex, students needed to rely on staged tasks, feedback mechanisms, and reflective activities within the BOPPPS-CDIO framework to develop their work progressively. Therefore, the local cultural information visualization project provided a meaningful and challenging learning context for structured project-based instruction in information design.

Interpreting the findings with caution

Although the quantitative results showed positive changes in students' perceived learning outcomes and individual project performance, the findings should be interpreted with caution. This study adopted a one-group pre-test and post-test design without a traditional teaching control group. Therefore, it cannot fully exclude the possible influence of time, course experience, students' natural development, or other learning activities. The questionnaire data were also self-reported and may have been influenced by social desirability, the course context, or students' perceptions of teacher expectations.

In addition, although individual work evaluation complemented the self-reported questionnaire data, the work scoring was conducted by the course teacher using a unified rubric, and the limited number of raters may have introduced potential rater bias. Open-ended

responses and learning reflection texts helped explain students' subjective learning experiences, but they cannot replace more objective external evaluation or authentic user testing. Therefore, the findings should be regarded as preliminary evidence of the pedagogical value of the BOPPPS-CDIO framework in a real course setting, rather than strong causal evidence of instructional effectiveness.

Nevertheless, the questionnaire results, work evaluation, open-ended responses, and reflection texts converged with one another. Students not only reported changes in perceived learning outcomes, but also showed positive changes in information hierarchy, visual clarity, and design completeness in their individual works. Their reflections also indicated shifts from visual decoration to information logic and from one-time submission to feedback-based revision. This convergence of multiple sources of evidence provides preliminary support for the instructional value of the framework.

Pedagogical implications

This study offers three pedagogical implications for information design courses and design education reform. First, information design courses should make the design process explicit rather than evaluate only final visual outcomes. Course assessment should include process-based components such as material collection, information classification, information hierarchy, user orientation, visual translation, feedback-based revision, and learning reflection. This may help students understand that information design is not visual decoration, but an information organization activity oriented toward user understanding and communication effectiveness.

Second, local cultural information visualization projects can serve as effective pedagogical carriers that connect cultural understanding with information expression. When students work with local cultural materials, they need to address complex issues of information selection, cultural-context understanding, and visual structure construction. Such projects can help students move beyond cultural symbol collage and further consider how cultural content can be transformed into visual information that users can understand.

Third, combining classroom structure with project process may support staged learning, formative feedback, and reflective transfer in design education. BOPPPS

helps teachers organize classroom rhythm, while CDIO helps students understand project progression. Their integration can provide an operational instructional pathway for project-based design courses, especially those requiring problem identification, solution development, work implementation, and feedback-based revision.

Conclusion

This study develops and implements a structured instructional framework that integrates the BOPPPS classroom teaching structure with the CDIO project process in an information design course using a local cultural information visualization project. The framework aligns classroom stages, including bridge-in, objective, pre-assessment, participatory learning, post-assessment, and summary, with project phases, including conceive, design, implement, and operate. It guides students through a complete learning process from understanding cultural materials, classifying information, and translating information visually to presenting final works.

The findings indicate positive changes in students' learning engagement, understanding of the information design process, project-based learning ability, information organization and visual expression ability, collaborative feedback and reflective learning, and learning satisfaction and transfer intention. The individual work evaluation further shows that students' final works perform better in information hierarchy, visual clarity, and design completeness. The open-ended responses and learning reflection texts suggest that students gradually shift from visual decoration to information logic, from passive assignment completion to active project development, and begin to understand the role of cultural information translation in design learning.

Overall, this study provides a structured, project-based, and feedback-driven instructional framework for information design courses in art and design education. The framework may have value for developing students' information organization ability, project-process awareness, feedback use, and cultural information visualization ability. Future research should further examine the framework through larger samples, control-group designs, external scoring, authentic user testing, and cross-course validation.

Limitations and future studies

This study has several limitations. First, it adopts a one-group pre-test and post-test design without a traditional teaching control group. Therefore, causal interpretation is limited. Although the pre-test and post-test results show positive changes across several dimensions, the findings cannot fully exclude the influence of time, course experience, or students' natural development. Future studies can include a control group to compare the BOPPPS-CDIO framework with traditional teaching approaches.

Second, the participants come from one course at one institution, and the sample scope was limited. Although the 60 students provide preliminary evidence within this course context, further research is needed to examine whether the findings can be applied to other institutions, year levels, design courses, or cultural project themes. Future studies can expand the sample and conduct cross-course, cross-institutional, or cross-programme comparisons.

Third, the questionnaire data are based on students' self-reports and may have been influenced by social desirability, the course context, and the teacher-student relationship. Although this study combines work evaluation, open-ended responses, and learning reflection texts, self-reported data cannot fully replace objective measures of learning performance. Future research can include external assessment, learning-process data, or authentic task-performance evaluation.

Fourth, the work evaluation is conducted by the course teacher using a unified rubric, and the limited number of raters may have introduced potential rater bias. Future studies can involve two or more external raters, use the same rubric for independent scoring, and report inter-rater reliability to strengthen the credibility of work evaluation.

Fifth, the local cultural information visualization works are mainly completed and evaluated within the classroom context and are not fully tested in authentic communication settings. Future research can include authentic user testing, external audience feedback, or online communication data to examine whether student works are readable, understandable, and communicatively effective in real-world contexts.

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Conflicts of Interest

The authors declare no conflict of interest.

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