

A Standards-Based Instructional Design for Assembly Drawing in Engineering Drawing: A Hydraulic Turbine Runner Case

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Abstract: Assembly drawing is a central component of Engineering Drawing education because it requires students to connect spatial cognition, structural analysis, standardized graphical expression, dimensioning, annotation, and engineering communication. Yet conventional instruction often depends on simplified textbook assemblies, which may not prepare students to interpret complex engineering equipment or to understand the documentation needs of manufacturing, assembly, and inspection. This paper proposes a concise, standards-based instructional design for teaching assembly drawing through a large hydraulic turbine runner. The runner contains blades, an upper crown, a lower ring, rotational geometry, curved surfaces, and fit-critical interfaces; therefore, it is suitable for teaching view selection, sectional representation, local enlarged views, item numbering, parts-list completion, assembly dimensions, installation dimensions, and technical requirements. The teaching framework integrates case-based learning, project-based tasks, and rubric-based assessment. Students are guided to analyze assembly relations, choose views according to communicative function, apply standard sectioning rules, complete necessary annotations, and evaluate drawing quality using explicit criteria. The proposed design turns a complex hydropower component into a teachable assembly-drawing project and offers a transferable model for improving students' engineering graphics competence.

1. Introduction

Engineering drawing remains a basic language for design, manufacturing, inspection, and technical communication. For undergraduate students in mechanical engineering and related majors, the Engineering Drawing course develops spatial thinking, graphical expression, standards awareness, and the ability to transform three-dimensional structures into precise two-dimensional documents. Recent studies on Engineering Drawing instruction have emphasized that the course contains abstract concepts, numerous standards, and detailed knowledge points, and that diversified resources and network-supported instructional design can help students connect professional

knowledge, drawing skills, and engineering habits [1], [2]. Although computer-aided design and digital product definition have changed the form of engineering information, students still need to read, construct, and interpret drawings accurately. Assembly drawings are especially important because they communicate component relationships, installation positions, fit requirements, item numbers, parts lists, and technical constraints.

Compared with part drawings or elementary projection exercises, assembly drawings impose higher cognitive and technical demands. Students must understand the working principle of a product, identify the relative position and connection of parts, select appropriate views and sectional views, apply standardized representation rules, and provide dimensions and technical notes without redundancy. In many courses, however, assembly drawing is still taught through simplified examples. Such examples are useful for introducing rules, but they are not sufficient for cultivating the ability to handle complex, function-oriented equipment. Students may reproduce drawing procedures in isolated exercises while still struggling to interpret real assemblies or to understand how annotations support manufacturing and inspection.

Recent technology-enhanced learning research is also relevant to this instructional problem. A systematic review of immersive virtual reality in science education indicates that spatial and interactive learning tasks should be supported by explicit learning objectives, cognitive-load control, learner guidance, and reflective activities [3]. Empirical studies further show that guided tutorials in immersive assembly learning can improve satisfaction, reduce time spent on operating the virtual environment, and strengthen understanding or evaluative knowledge [4]; immersive STREAM instruction can enhance learning achievement and motivation [5]; curriculum-aligned immersive virtual reality can improve factual knowledge and comprehension in an authentic electrical-engineering classroom [6]; and immersive environments can improve important aspects of learning experience compared with web-based or desktop alternatives [7]. These findings suggest that complex assembly-drawing teaching should combine authentic objects, guided procedures, and explicit standards rather than rely on either textbook simplification or digital visualization alone.

Large hydropower equipment provides an authentic context for addressing this problem. As a core component of a hydraulic turbine, the runner contains blades, an upper crown, a lower ring, curved surfaces, rotational structure, and interfaces that affect fit and installation. Its assembly drawing requires coordinated use of a main view, sectional views, local enlarged views, item numbers, a parts list, fit dimensions, installation dimensions, overall dimensions, and technical requirements. These features make the runner a meaningful case for helping students move from rule memorization to standards-based engineering communication.

Modern engineering documentation also requires students to understand why standards matter. Dimensions, tolerances, geometric specifications, notes, and product data must express design intent in a form that can be interpreted by multiple users. Therefore, Engineering Drawing education should not stop at teaching students to draw lines neatly. It should help them judge whether a drawing is complete, readable, standards-compliant, and useful for downstream engineering activities. This requirement is the basis for introducing an authentic runner assembly into the classroom.

To turn these requirements into a teachable module, the present study adopts a case-based and project-oriented design. A recent systematic review of flipped learning reports that structured pre-class learning and active in-class engagement can strengthen students' self-efficacy across different age groups and subject domains [8]. Accordingly, this paper presents a standards-based instructional design for assembly drawing using a large hydraulic turbine runner as the case. The design combines case-based learning, project-based tasks, and standards-oriented drawing training. It guides students to analyze structure and assembly relations, choose views and sectional representations, annotate essential dimensions, complete item numbering and a parts list, and

evaluate drawing quality with a structured rubric. The contribution of the paper is threefold: it transforms a complex hydropower component into a teachable Engineering Drawing case; it links structural analysis, graphical representation, dimensioning, annotation, and evaluation into a coherent teaching procedure; and it offers a transferable model for improving students' engineering graphics competence through authentic, standards-based instruction.

2. Research Design and Instructional Framework

This study adopts a design-based instructional research perspective. Its purpose is not merely to describe the drawing procedure of a hydraulic turbine runner, but to organize a complex assembly into a structured learning task through which students can develop spatial cognition, assembly-relation interpretation, standards-compliant drawing ability, and engineering communication competence. In the framework, the runner serves as the authentic engineering case, and the teaching process is organized around assembly analysis, view selection, sectional representation, dimensioning, annotation, and drawing-quality evaluation.

The instructional design follows three principles. First, the task should be authentic. Assembly drawing is closely related to design, manufacturing, assembly, inspection, and maintenance. Students therefore need contact with representative engineering products rather than only simplified textbook objects. The hydraulic turbine runner is selected because it contains typical features of large mechanical assemblies: blades, an upper crown, a lower ring, rotational geometry, complex curved surfaces, and fit-critical interfaces. These features help students understand why assembly drawings require appropriate views, sections, item numbers, parts lists, dimensions, tolerances, and technical requirements.

Second, the learning process should be standards-based. Engineering drawings are governed by shared conventions, not by personal drawing habits. In assembly drawings, students must understand how adjacent parts are represented, how contacting and non-contacting surfaces are distinguished, how hatch lines are arranged, how standard solid parts are treated in longitudinal sections, and how simplified or special representations are used when appropriate. More importantly, they must recognize that an assembly drawing does not include every part dimension; it should include information required for performance, assembly, installation, overall structure, and important engineering functions.

Third, the outcomes should be measurable. The framework evaluates students' assembly-drawing competence through four observable aspects: representation adequacy, annotation validity, standards compliance, and engineering readability. Representation adequacy refers to whether the selected views, sectional views, and local details express the structure and assembly relations of the runner. Annotation validity concerns whether dimensions, fits, item numbers, the parts list, and technical requirements are complete and unambiguous. Standards compliance refers to line types, hatching, sectioning rules, dimension placement, and drawing-sheet organization. Engineering readability examines whether the drawing can be understood by designers, manufacturers, inspectors, and other readers without unnecessary confusion.

The overall design contains four stages. First, the teacher analyzes the structural features and assembly relations of the runner and translates them into drawing-learning points. Second, a teaching module is prepared, including structural schematics, simplified assembly-relation diagrams, drawing-task sheets, and assessment criteria. Third, students complete the assembly-drawing task by analyzing the working principle, determining the view scheme, constructing the graphical expression, and adding dimensions and annotations. Fourth, drawings are evaluated through a rubric and typical errors are summarized to improve instruction. Through these stages, assembly drawing is presented as engineering reasoning and communication rather than mechanical reproduction of

lines.

To keep the case teachable, the runner is decomposed into several instructional units. The first unit focuses on structural cognition and helps students identify the spatial relationship among the blades, upper crown, lower ring, and installation interfaces. The second unit focuses on view selection and asks students to determine the main view according to the working position and principal assembly relation. The third unit focuses on sectional representation, including cutting-plane selection, hatching, and the representation of contact and non-contact surfaces. The fourth unit focuses on local expression for dense or fit-critical regions. The fifth unit integrates dimensioning, item numbering, parts-list completion, and technical requirements. This modular structure reduces cognitive overload while preserving the authenticity of the engineering case.

3. Teaching Design for Runner Assembly Drawing

3.1. Objectives and Case Preparation

The learning objectives are divided into knowledge, ability, and professional-quality objectives. The knowledge objectives require students to understand the content and rules of assembly drawings, including view selection, sectional views, local enlarged views, item numbers, parts lists, dimensions, technical requirements, and drawing conventions. Students should also distinguish assembly drawings from part drawings: part drawings define the manufacturing information of one component, whereas assembly drawings focus on relationships among parts, assembly accuracy, installation conditions, and functional interfaces.

The ability objectives emphasize the transformation from three-dimensional product understanding to two-dimensional standardized expression. Students should be able to analyze the structural composition of the runner, identify the relations among blades, upper crown, lower ring, and installation interfaces, select views that express these relations, use sectional views to reveal internal structures, use local enlarged views to clarify fit-critical regions, and complete necessary dimensions and annotations without ambiguity. The professional-quality objectives cultivate rigorous engineering habits. Students should understand that inaccurate line types, missing item numbers, unclear dimensions, or vague technical requirements may cause misunderstanding in downstream work.

Before drawing, the teacher introduces the engineering background and main structural features of the runner. Three resources are prepared: a three-dimensional model or structural schematic for spatial cognition, a simplified assembly-relation diagram for the relative positions of major components, and a drawing-task sheet that defines expected outputs. The teacher does not provide the final drawing scheme directly. Instead, students are guided to answer key questions: Which components form the main assembly relation? Which surfaces determine relative position? Which structures are visible from the outside, and which require sectioning? Which regions need local enlargement? These questions shift learning from passive imitation to active engineering analysis.

3.2. View Selection, Sectional Representation, and Layout

View selection is the first core task. The main view should be chosen according to the working position of the assembly and the principal assembly relationship, rather than simply according to the largest outline. For the hydraulic turbine runner, the main view should express the rotational structure and the relation among the upper crown, blades, and lower ring. Supporting views are then added to compensate for information that the main view cannot show clearly. Because many important relations are located inside connection regions, sectional views are necessary. Local enlarged views can be used for blade-root regions, dense connection structures, or fit-critical

interfaces where ordinary scale would cause ambiguity.

Sectional representation is the technical focus of the task. Students apply standard assembly-drawing conventions: contacting surfaces between adjacent parts are expressed as one contour line, non-contacting surfaces are represented separately, adjacent parts use different hatching directions or spacing, and the same part keeps consistent hatching in different views. For standard solid components, such as shafts, pins, keys, balls, and threaded fasteners, longitudinal sections follow conventional representation rules. In the runner case, sectioning helps students reveal hidden relations and distinguish part geometry from assembly relationship.

Special representation methods may be introduced when they reduce complexity without weakening accuracy. For example, a removed section can clarify a local connection, a simplified representation can avoid repeated blade details, and a local enlarged view can separate dense dimensions from the main view. However, simplification must be explained as a standards-based decision rather than a shortcut. Students are asked to justify which information is kept, which is omitted, and why the final expression remains sufficient for engineering communication.

The layout is arranged for readability. Students determine the sheet, scale, title block, and space for the parts list before drawing. They then place the main view, sectional view, and local enlarged view in a logical order and reserve adequate space for dimensions, item numbers, section labels, and technical notes. The teacher emphasizes that layout is not decoration but communication. A crowded layout may make correct information difficult to interpret, whereas a balanced layout helps readers understand the assembly quickly.

3.3. Dimensioning, Annotation, and Parts List

Dimensioning in assembly drawings follows a different logic from dimensioning in part drawings. The aim is not to mark every component dimension, but to provide dimensions needed for function, assembly, installation, and inspection. In the runner case, assembly dimensions define relative positions and fit relations among the blades, upper crown, lower ring, and interfaces. Installation dimensions guide the connection between the runner and related equipment. Overall dimensions describe the space occupied by the assembly. Specification dimensions and other important dimensions communicate necessary engineering information without turning the assembly drawing into a collection of part drawings.

Annotations must support interpretation. Item numbers should be arranged clearly and correspond accurately to the parts list. The parts list should include part names, quantities, materials, or other required identification information. Technical requirements should be concise and should address assembly, fit, inspection, balance, surface treatment, or other conditions relevant to the runner. A key teaching point is the prevention of ambiguous annotation. For curved-surface components such as runner blades, students need to understand datum selection, surface-parameter expression, and inspection requirements so that manufacturing and verification can be performed consistently.

3.4. Classroom Implementation

The module is implemented as a project-based learning process. Before class, students receive structural images, simplified assembly diagrams, and the task sheet. They preview the runner structure and prepare initial questions. During class, the teacher explains the working principle and assembly structure, then organizes group discussion on the main view, sectional view, local enlarged view, and key dimensions. Students compare several expression schemes and justify their choices according to standards and communicative needs. After that, they complete the drawing step by step, moving from structure analysis to layout, graphical expression, dimensions, item

numbers, parts list, and technical requirements.

After class, students submit the drawing for rubric-based assessment. Feedback focuses not only on graphical correctness but also on representation adequacy, annotation validity, standards compliance, and readability. Students also complete a short self-check form in which they explain their view-selection logic, the purpose of each sectional view, the dimensioning categories used, and the location of important technical notes. Peer discussion can be organized before final submission so that students compare different representation schemes and discover ambiguity in their own drawings. Typical errors are collected and used as follow-up teaching materials. Through this cycle, students learn to view the assembly drawing as a technical document that must communicate design intent to multiple engineering readers.

4. Evaluation Method

4.1. Drawing Tasks and Assessment Rubric

Table 1: Assessment rubric for the runner assembly-drawing task

Evaluation dimension	Main assessment content	Scoring focus
Structural understanding	Major components, interfaces, and assembly relations	Correctly identifies components and relative positions
View selection	Main view, supporting views, local enlarged views, and layout	Views express principal assembly relations clearly
Sectional representation	Cutting plane, hatching, contact surfaces, hidden structures	Sections reveal internal relations and follow conventions
Dimensioning	Assembly, installation, overall, specification, and key dimensions	Dimensions are necessary, complete, clear, and non-redundant
Annotation and technical requirements	Fit notes, installation notes, inspection notes, and technical statements	Annotations support manufacturing, assembly, and inspection
Item numbering and parts list	Item numbers, part names, quantities, and material information	Numbering and parts-list information are accurate
Standards compliance	Line types, hatching, dimension placement, title block, scale, and format	Drawing follows technical drawing conventions
Engineering readability	Overall clarity, organization, ambiguity control, and communicability	Readers can interpret the drawing without confusion

The evaluation combines drawing-task assessment, rubric-based scoring, error analysis, and student feedback. The goal is to examine whether students can understand assembly relations, select suitable representations, apply dimensioning rules, and produce a standards-compliant document. Two tasks can be used. The first is a conventional assembly-drawing task from course materials,

which provides a baseline for students' general drawing ability. The second is the hydraulic turbine runner task, which requires students to apply the complete instructional framework. This arrangement helps identify whether the runner module improves performance beyond routine exercises.

The runner task asks students to analyze the relation among blades, upper crown, lower ring, and installation interfaces; determine the main view; select sectional and local enlarged views; apply hatching and line conventions; annotate specification, assembly, installation, overall, and other important dimensions; complete item numbers and the parts list; and write concise technical requirements. The task sheet provides engineering background and expected outputs but does not give the final layout, so students must make their own representation decisions.

To avoid evaluating only the final appearance, the teacher may also collect intermediate learning products, such as view-selection sketches, assembly-relation analysis sheets, dimensioning plans, and self-check forms. These materials show how students transform three-dimensional understanding into two-dimensional representation and help locate the source of errors. For example, a wrong sectional view may result from weak spatial cognition rather than from poor drawing technique; a missing installation dimension may indicate confusion between part drawing and assembly drawing.

A structured rubric is used to evaluate student drawings. Each dimension can be scored on a five-point scale: 5 means that the drawing fully satisfies the requirement; 4 indicates minor omissions; 3 indicates basic expression with noticeable problems; 2 indicates major errors that affect interpretation; and 1 indicates failure to communicate required assembly information. Table 1 summarizes the rubric.

4.2. Scoring, Error Analysis, and Feedback

To improve objectivity, at least two raters assess each drawing. Raters may include Engineering Drawing teachers, mechanical design instructors, or engineers familiar with hydropower equipment drawings. Before scoring, they review sample drawings and rubric criteria to establish common judgment standards. If the score difference exceeds a set threshold, a third rater reviews the drawing or the raters discuss the disagreement. In addition to total scores, dimension-level scores are analyzed because a student may produce a neat layout but fail to express a blade-root relation, or select a useful sectional view but omit installation dimensions.

Error analysis reveals typical learning difficulties and informs teaching improvement. Errors are classified as view-selection errors, sectional-expression errors, assembly-relation errors, dimensioning errors, annotation errors, item-numbering errors, and standards-compliance errors. For example, view-selection errors occur when the main view does not show the principal assembly relation. Sectional-expression errors include unsuitable cutting planes, incorrect hatching, and failure to distinguish adjacent parts. Dimensioning errors include missing assembly dimensions, repeated dimensions, unreasonable dimension chains, unclear installation dimensions, or excessive part-level dimensions. The distribution of errors shows which teaching points need additional explanation or practice.

Student feedback supplements drawing scores. A questionnaire may ask students whether the runner case helps them understand assembly relations, view selection, standards compliance, and engineering communication. Open-ended questions can identify which part of the task was most difficult and which teaching resources were most useful. The final evaluation therefore combines objective drawing quality, process evidence, error analysis, and learning reflection.

5. Conclusions

This paper proposed a concise standards-based instructional design for teaching assembly drawing in Engineering Drawing, using a large hydraulic turbine runner as an authentic case. The design addresses a limitation of traditional instruction: students often learn rules through simplified examples but lack opportunities to apply them to complex assemblies. By introducing the runner, the teaching module connects drawing knowledge with engineering structure, assembly relations, manufacturing communication, and standards-compliant documentation.

The framework organizes learning around structural analysis, view selection, sectional representation, dimensioning, annotation, item numbering, parts-list completion, and technical requirements. It also provides a rubric for evaluating structural understanding, view selection, sectional representation, dimensioning, annotation validity, item numbering, standards compliance, and readability. This rubric helps teachers identify specific learning difficulties and gives students clear criteria for improving drawing quality.

The approach is not limited to hydraulic turbine runners. Teachers can extend the same logic to pumps, compressors, engines, gearboxes, turbines, and other complex assemblies. Future studies should validate the instructional design through classroom data, including pre- and post-task scores, expert ratings, error distributions, and student feedback. Digital models, exploded views, animation, and model-based annotation may also be integrated to support spatial understanding. Overall, the runner case provides a practical pathway for making assembly-drawing instruction more authentic, systematic, and outcome-oriented.

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References

- [1] Yang, S.L., Yin, S.X. and Zhu, W.B. (2023) *Instructional Design Integrated with Curriculum Politics for Engineering Drawing Based on a Network Teaching Platform*. *Curriculum and Teaching Methodology*, 6, 92-98.
- [2] Yang, S.L., Yin, S.X. and Zhu, W.B. (2023) *A Novel Instructional Design for the Course of Engineering Drawing under the Emerging Network Teaching*. *Advances in Educational Technology and Psychology*, 7, 79-84.
- [3] Lui, A.L.C., Not, C. and Wong, G.K.W. (2023) *Theory-Based Learning Design with Immersive Virtual Reality in Science Education: A Systematic Review*. *Journal of Science Education and Technology*, 32, 390-432.
- [4] Miguel-Alonso, I., Checa, D., Guillen-Sanz, H. and Bustillo, A. (2024) *Evaluation of the Novelty Effect in Immersive Virtual Reality Learning Experiences*. *Virtual Reality*, 28, 27.
- [5] Astatke, M., Weng, C., Yohannes, A., Isaac, M.M. and Liou, W.K. (2024) *Influences of Immersive Virtual Reality (IVR)-Based Science, Technology, Religion, Engineering, Art, and Mathematics (STREAM) Instructional Approach on Students' Learning Performances*. *Educational Technology Research and Development*, 72, 2921-2938.
- [6] Spangenberger, P., Matthes, N., Kapp, F., Kruse, L. and Plass, J.L. (2025) *Orchestrating iVR Technology in an Authentic Classroom Setting and Its Effects on Factual Knowledge, Comprehension and Transfer*. *Educational Technology Research and Development*, 73, 387-413.
- [7] Antonopoulos, P., Fokides, E. and Koutromanos, G. (2025) *Understanding Learning and Learning Experience in Immersive Virtual Reality*. *Technology, Knowledge and Learning*, 30, 1771-1800.
- [8] Algarni, B. (2025) *Impact of Flipped Learning on Student Self-Efficacy Across Age Groups and Subject Domains: A Systematic Review of 44 Studies (2015-2024)*. *Journal of Information Technology Education: Research*, 24, 004.