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# *Developing Part-Drawing Competence through a Hydropower Turbine Runner Case in Engineering Drawing*

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***Abstract:*** Engineering Drawing is a fundamental course for engineering students because it trains the ability to express, read and communicate technical information. In conventional teaching, however, drawing standards are often taught as separate rules, such as view selection, dimensioning, line conventions, section representation, tolerances and technical requirements. This fragmented approach may weaken students' ability to produce complete and standardized part drawings for complex engineering components. This paper proposes a concise standards-based instructional design for part-drawing education by using a large hydropower turbine runner as an authentic case. The runner case contains blades, upper crown, lower ring, shaft-related parts, curved surfaces, transition structures, dimension chains, surface roughness, geometrical tolerances and inspection datum requirements. The proposed framework organizes part-drawing teaching into eight dimensions: view layout, title block, dimensioning, line conventions, section-line conventions, technical requirements, in-drawing technical annotations and graphic drawing workflow. Through case introduction, structure analysis, view planning, standardized drawing, technical annotation and drawing checking, students are guided to understand part drawings as technical documents for design, manufacturing, assembly and inspection.

## 1. Introduction

Engineering Drawing is a basic course in engineering education and a common graphical language in mechanical engineering. It connects design, manufacturing, assembly, inspection and maintenance. In particular, a part drawing is not only a representation of shape, but also a technical document that defines dimensions, tolerances, surface quality, material information, manufacturing requirements and inspection references. Recent studies on Engineering Drawing instruction have emphasized that the course should develop students' drawing expression, technical reading and engineering communication abilities rather than only train them to memorize drawing symbols [1,2]. Therefore, the teaching of Engineering Drawing should help students understand drawings as formal engineering communication documents.

Engineering Drawing courses usually include projection theory, view representation, section views, dimensioning, part drawings, assembly drawings and drawing standards. These contents support later courses such as mechanical design, computer-aided design and manufacturing technology. Nevertheless, the course contains many detailed rules and abstract spatial concepts. Students may know isolated rules, such as line types or section hatching, but still find it difficult to integrate these rules into a complete and standardized part drawing. Recent work on engineering-course reform and online teaching design also suggests that fragmented knowledge should be reorganized into task-based and application-oriented learning activities [3,4].

Standardization is central to part-drawing education. A small error in view selection, dimensioning, tolerance annotation or technical requirements may cause ambiguity in manufacturing and inspection. A complete part drawing should therefore include reasonable view layout, correct title-block information, clear dimensions, proper line and section-line conventions, written technical requirements, dimensional tolerances, surface roughness and geometrical tolerances. Studies on technical drawing teaching under digital and blended learning environments further show that students need explicit guidance to connect drawing rules with drawing practice [5].

Recent higher-education research shows that generative-AI-supported tutoring and peer-feedback tools can provide timely assistance and support student engagement when embedded in purposeful learning activities [6,7]. However, their educational use requires explicit pedagogical guidance, transparent institutional policies, ethical safeguards, and assessment practices that protect academic integrity [8,9]. For Engineering Drawing, this means that CAD software, online materials and digital examples should support, not replace, students' own reasoning about view selection, dimensioning, datum choice and standard-based technical expression.

Traditional classroom examples are often simplified so that beginners can learn basic rules. This is necessary, but simplified examples may not fully reveal the complexity of real engineering products. As a result, students may develop fragmented knowledge of drawing standards but lack the ability to apply them to authentic engineering situations. In Engineering Drawing, students should learn how to select views, arrange dimensions, define datums, specify tolerances and write technical requirements according to part function and manufacturing needs.

A large hydropower turbine runner is a suitable case for this purpose. As a core component of a hydropower unit, it involves structural relationships among blades, upper crown, lower ring, shaft-related parts and connecting features. Its part drawings require clear view planning, expression of complex curved surfaces and transition structures, rational dimension chains, dimensional and geometrical tolerances, surface roughness symbols, profile parameters and inspection datums. Compared with ordinary classroom parts, the runner case can better show how standardized drawing expression supports manufacturing, assembly, inspection and quality assurance in major equipment engineering.

Based on this teaching need, this paper proposes a standards-based instructional design for Engineering Drawing. It takes the hydropower turbine runner as an authentic case and organizes part-drawing teaching around eight dimensions: view layout, title block, dimensioning, line conventions, section-line conventions, technical requirements, in-drawing technical annotations and graphic drawing workflow. The purpose is to provide a transferable teaching model that links drawing standards, complex engineering components and engineering communication ability.

## 2. Course Context and Teaching Problem

Part drawing is a key unit in Engineering Drawing because it requires students to use several knowledge points at the same time. Students must understand projection, select proper views, apply line types, use sections, arrange dimensions, fill in the title block and add technical requirements. They must also understand that the drawing will be read by others for manufacturing, inspection and assembly. This integrative feature makes part drawing an important bridge between basic graphical knowledge and engineering practice.

In classroom teaching, however, students often learn the elements of a part drawing separately. For example, title blocks may be taught as document information, dimensioning as a rule set, and geometrical tolerancing as a symbol system. When students face a complete drawing task, they may not know how these elements work together. A drawing may appear complete in shape but still be weak in manufacturing logic, datum selection, tolerance expression or inspection clarity.

The teaching problem can therefore be summarized as the gap between rule knowledge and engineering application. To narrow this gap, part-drawing education should shift from "drawing a shape" to "communicating an engineering object." Students need a structured case in which every drawing decision has a technical reason. View layout should be related to structure; dimensioning should be related to manufacture and measurement; tolerances should be related to function; and technical requirements should be related to process and quality control.

The hydropower turbine runner case meets this need because it is complex but teachable after educational transformation. It contains enough engineering features to support standards-based learning, while selected parts such as blades or shaft-related components can be simplified for undergraduate teaching. The case can guide students to connect assembly function with part-level expression and to understand why drawing standards matter in real engineering communication.

From the perspective of outcome-based engineering education, this teaching problem is also related to students' ability to apply professional knowledge in realistic contexts. A qualified part drawing should show not only spatial imagination, but also awareness of standards, process constraints and communication responsibilities. Therefore, the learning objective of the module is expressed as an integrated competence: students should be able to read the function of a part, choose an expression scheme, complete technical annotations and check whether the drawing can be used by others.

This competence cannot be developed only by explaining isolated symbols. It requires a task that has clear engineering background and enough structural complexity. The runner case allows the teacher to connect basic drawing knowledge with a meaningful product scenario. It also gives students a concrete reason to learn strict drawing rules, because each rule is linked to manufacturing, measurement or quality assurance.

## 3. Educational Transformation of the Hydropower Turbine Runner Case

The hydropower turbine runner was selected because it represents a typical component in large-scale equipment manufacturing. At the assembly level, the runner includes blades, upper crown, lower ring and related shaft or connecting structures. At the part level, representative components contain complex curved surfaces, transition areas, functional surfaces and strict technical requirements. These features provide rich teaching material for view selection, section expression, dimension chains, tolerance specification, surface roughness and inspection datums.

The original engineering object cannot be directly used as a complete classroom drawing task. Industrial drawings may involve confidential parameters, excessive process information and details beyond the scope of a basic Engineering Drawing course. Therefore, the case should be transformed into a teachable version. Non-essential details can be simplified, confidential dimensions can be replaced by instructional data, and the task can focus on representative drawing problems rather than the full industrial product.

The transformation follows three principles. First, the case should preserve the functional logic of the runner so that students can understand why a certain view, section, dimension, tolerance or datum is needed. Second, the case should match the knowledge points of part drawing, especially view layout, dimensions, technical requirements, tolerance annotation and surface quality. Third, the task should be manageable for students who have already learned basic views, sections and dimensioning. In this way, the runner is not merely a visual example, but a structured learning object for standards-based drawing education.

The case can be decomposed from assembly understanding to part drawing. Students first recognize the relationship among runner components and then focus on a representative part. A blade is suitable for teaching curved surface expression, profile control, transition structures and inspection datum selection. A shaft-related part is suitable for teaching rotational structures, sections, diameter dimensions, coaxial relations, surface roughness and tolerance requirements. This decomposition helps students understand how a complex engineering product is represented through different levels of technical drawings.

In teaching, the teacher may first show the overall runner structure and then gradually reduce the task to one selected part. This "whole-to-part" route is important. If students start directly from a single contour, they may treat the drawing as a geometric exercise. If they first understand how the part works in the runner, they can better decide which surface is functional, which axis or plane can serve as a reference, and which requirements should appear in the technical notes.

The simplified case should also keep a proper degree of difficulty. Over-simplification would make the task similar to ordinary textbook examples, while excessive complexity would distract students from the main learning objectives. A balanced case should include at least one complex surface or transition feature, one section or local expression problem, one dimension-chain problem and one tolerance or roughness annotation problem.

## 4. Standards-Based Instructional Framework

The core of the proposed design is an eight-dimension framework for part-drawing standardization. These dimensions cover the main elements of a complete part drawing and provide a clear structure for teaching, practice and checking. The framework helps transform scattered drawing rules into an integrated learning system. It also helps teachers organize case explanation in a logical order: from expression planning to graphic construction, then to dimensions, technical requirements and final checking.

The eight dimensions are arranged according to the general workflow of drawing production. View layout and title-block information establish the document form; line and section conventions construct the graphical expression; dimensioning and technical annotations define the manufacturing and inspection requirements; technical notes supplement general process information; and final workflow checking ensures the drawing is complete and coherent. This order helps students understand the hierarchy of part-drawing information. Eight-dimension framework for hydropower runner part-drawing teaching is shown in Table 1.

In this framework, view layout is the first step because it determines whether the part can be understood clearly. For a runner blade, the main view should reveal the main profile and functional surfaces, while a section or local enlarged view may be needed for transition areas. For shaft-related parts, section views and center lines are important for expressing rotational features and coaxial relations.

Dimensioning is the central link between drawing and manufacturing. Dimensions should not be placed only according to empty space on the sheet. They should reflect functional references, machining sequence and inspection convenience. For runner parts, dimension chains must avoid repetition and closed loops, and key surfaces should be related to appropriate datums.

Table 1: Eight-dimension framework for hydropower runner part-drawing teaching

| Dimension | Teaching focus | Runner-case application | Checking focus |
|---|---|---|---|
| View layout | Main view, section view, auxiliary view and local view | Express blade, crown, ring, shaft or transition area clearly | Complete, concise and non-redundant views |
| Title block | Drawing number, part name, material, scale and document data | Complete formal information for the selected part | Accurate and standardized document information |
| Dimensioning | Defining, locating, overall and functional dimensions | Arrange dimensions according to manufacturing and inspection logic | Clear, complete and non-repetitive dimensions |
| Line conventions | Visible lines, hidden lines, center lines and dimension lines | Draw contours, axes, holes and transitions | Correct line type and graphical hierarchy |
| Section-line conventions | Section views, hatching direction and spacing | Express internal structures or transition features | Readable and standard section expression |
| Technical requirements | General notes on fillets, chamfers, heat treatment or deburring | Write concise requirements for the runner part | Clear, ordered and process-related wording |
| Technical annotations | Dimensional tolerance, roughness, GD&T, datums and profile control | Annotate functional surfaces and inspection references | Consistency with function and inspection needs |
| Drawing workflow | Scale, layout, baselines, contour drawing, annotation and checking | Complete the drawing from planning to final review | Systematic process and neat drawing quality |

Technical annotations are the most difficult but also the most meaningful part of the framework. Dimensional tolerances, roughness, geometrical tolerances and datum symbols express design intent and quality requirements. In the turbine runner case, curved profiles, contact surfaces, shaft-related axes and assembly interfaces all provide opportunities to explain why tolerances and inspection references must be carefully specified.

The framework also emphasizes drawing workflow. Students should first plan the sheet and baselines, then draw contours and sections, then add dimensions and technical annotations, and finally check the drawing as a complete document. This order helps students avoid the common habit of drawing geometry first and adding technical information only at the end without sufficient logic.

The title block and written technical requirements should not be ignored in teaching. Beginners often regard them as peripheral information, but they determine the formal identity and production meaning of the drawing. Material, scale, drawing number and part name support document management, while notes on unmarked chamfers, heat treatment, deburring or inspection conditions supplement information that cannot be conveniently placed in the view area.

Line conventions and section-line conventions should be taught through comparison. For example, visible contours, hidden structures, center lines, cutting-plane lines and dimension lines should form a clear graphical hierarchy. In section views, hatching direction, spacing and boundary treatment directly affect readability. When students compare standard and non-standard examples, they can more easily understand that line rules are not decorative details but part of the language of engineering drawings.

For the turbine runner, technical annotation is closely related to function. A surface involved in assembly, water-flow performance or rotational accuracy may require stricter roughness or geometrical control than a non-functional surface. Therefore, the teacher should guide students to ask why a symbol is needed before asking where it should be placed. This helps avoid mechanical symbol copying and promotes functional reasoning.

## 5. Teaching Design and Classroom Implementation

The teaching design follows the sequence of "case introduction—structure analysis—view planning—standardized drawing—technical annotation—checking and improvement." It is not an experimental procedure, but a practical classroom organization method for integrating standards with a complex engineering case. The goal is to make students experience the complete logic of a part drawing while keeping the task within the scope of the Engineering Drawing course.

The sequence can be integrated into two to four class hours according to the course schedule. In a shorter arrangement, the teacher may use the runner blade only as a demonstration case. In a longer arrangement, students may complete a simplified part drawing after class. In both cases, the emphasis should be on the logic of standard expression rather than on excessive geometric details. Table 2 shows the teaching sequence of the hydropower runner part-drawing module.

Table 2: Teaching sequence of the hydropower runner part-drawing module

| Teaching stage | Main activity | Expected learning focus |
|---|---|---|
| Preparation | Provide runner background, simplified models, task sheet and drawing-standard checklist | Understand the engineering context and review basic standards |
| Structure analysis | Analyze assembly relations among blade, upper crown, lower ring and shaft-related parts | Connect part expression with assembly function |
| View planning | Select main view, section view, auxiliary view and local enlarged view | Express complex geometry clearly and economically |
| Drawing and annotation | Draw contours, sections, dimensions, roughness, tolerances and technical requirements | Integrate graphical expression and technical specification |
| Checking and improvement | Use the eight-dimension checklist to review and revise the drawing | Develop standardization awareness and document-quality thinking |

Before class, students review basic knowledge of part drawings and study simplified materials related to the turbine runner. These materials may include three-dimensional models, assembly relationship diagrams, examples of standard part drawings and a concise task sheet. The purpose is to help students enter the classroom with a preliminary understanding of the runner structure and the drawing requirements.

The task sheet should clearly define the expected drawing output. It may specify the selected part, drawing scale, required views, basic dimensional information and technical requirements to be considered. At the same time, it should leave enough space for students to make decisions, such as choosing a local enlarged view or selecting a proper datum. This design combines guidance with autonomy.

In class, the teacher first introduces the engineering background of the runner and explains why standardized part drawings are important for large equipment manufacturing. The teacher then guides students to analyze structural relationships and functional surfaces. This stage should focus on questions such as: Which surfaces are functional? Which features affect assembly? Which structures require section views? Which surfaces should be used as dimensioning references? These questions make students aware that drawing decisions are based on engineering function rather than personal preference.

After structure analysis, students plan the expression scheme. For a blade, the teaching focus may include the selection of a view basis, expression of curved surfaces, transition areas and profile features. For a shaft-related part, the focus may include axial structure, sections, diameter dimensions, coaxial relations and surface quality. The teacher can compare several view schemes and explain why one scheme is clearer or more economical than another.

Technical annotation should be treated as a separate teaching focus rather than as an appendix to geometry. Students are guided to identify functional surfaces and inspection references before adding roughness symbols, dimensional tolerances and geometrical tolerances. For runner components, profile-related requirements and datum selection can be used to explain the relationship among design intent, manufacturing accuracy and inspection method.

Finally, students check and improve the drawing according to the eight-dimension framework. The checklist encourages them to ask whether the drawing is complete, clear, standardized, manufacturable and inspectable. This process changes the learning focus from “finishing a drawing” to “producing a reliable engineering document.” Teachers may use examples of typical non-standard drawings to guide discussion, but the emphasis should remain on drawing logic and standards rather than on score comparison.

## 6. Conclusions

This paper proposes a standards-based instructional design for Engineering Drawing by using the part drawing of a large hydropower turbine runner as an authentic case. The design responds to a common problem in part-drawing teaching: students may learn drawing rules separately but have difficulty integrating them into a complete and standardized engineering document.

The proposed framework organizes part-drawing teaching around eight dimensions: view layout, title block, dimensioning, line conventions, section-line conventions, technical requirements, in-drawing technical annotations and graphic drawing workflow. These dimensions transform scattered rules into a systematic learning structure and help students understand whether a drawing is not only visually complete, but also readable, manufacturable and inspectable.

The hydropower turbine runner enriches Engineering Drawing teaching because it contains complex curved surfaces, transition structures, assembly relations, dimension chains, surface quality requirements, geometrical tolerances and inspection datums. Through this case, view selection can be connected with structure expression, dimensioning with manufacturing and measurement, and tolerance or roughness annotation with functional surfaces and inspection needs.

In conclusion, integrating a large hydropower turbine runner into part-drawing teaching provides a meaningful path for linking drawing standards with real engineering practice. The proposed design offers practical reference for cultivating students' standards-based drawing competence, engineering communication awareness and rigorous professional habits in Engineering Drawing courses.


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