Reverse Instructional Design for Secondary Vocational Mechanical Foundations Based on Holistic Unit Planning

Yuting Yang, Yonghuan Guo*

School of Mechanical Engineering, Jiangsu Normal University, Xuzhou, 221116, China

*Correspondence: gyh8421@126.com

Abstract. Good design is not merely about imparting knowledge and skills to students, but rather it aims to generate a more comprehensive and concrete learning experience by being directed towards the objectives and their underlying implications. When designing lessons, units, and courses, we do not derive from familiar pedagogical methods, textbooks, and activities. Instead, we start with the desired learning outcomes. The most impactful designs are those that think "end-to-beginning," initiating from the learning result and working backwards. This paper exemplifies this approach by exploring reverse instructional design for the unit on Chain Drives Chapter 3 in the 7th edition of the Mechanical Foundations textbook. We investigate the design of Mechanical Foundations based on holistic unit planning, which involves first defining the anticipated outcomes, then identifying suitable assessment evidence, and finally crafting the learning experiences. This method aims to enhance teaching effectiveness and advance the realization of core competencies in students.

Keywords: Mechanical foundations, Reverse instructional design, Holistic unit planning, Anticipated outcomes, Assessment evidence, Learning experiences.

1 Introduction

On China's quest from manufacturing giant to global innovator, vocational education is key, with secondary vocational schools as its bedrock. Yet, these schools face societal undervaluation and student disengagement. Urgently needed: visionary teaching strategies to reawaken students' inspiration and reignite their ambitions.

In traditional instructional design for mechanical fundamentals, instructors typically follow a forward-thinking approach, progressing from objectives to content, then to delivery methods, and culminating in assessment. In classrooms, it's common to see teachers sticking to an input-focused approach, where it's mostly one person talking and everyone else listening. Students usually don't dig deep. they skim the surface of what they're learning without clear goals, kinda treating their heads like storage bins for info.

To address the limitations of existing teaching practices, it is necessary to innovate educational philosophies tailored to the characteristics of the mechanical discipline, thereby broadening the horizons of instructional design[1]. As an emerging pedagogical

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concept, the backward design model adopts a holistic perspective, prioritizes understanding, and promotes teaching through assessment. Given the practical attributes of the backward design model, this paper builds upon theoretical foundations and empirical outcomes of backward design. Focusing on the cultivation pathway of core disciplinary competencies, and incorporating the instructional design element of unit-wide conceptualization, we propose a teaching framework for the secondary vocational "Mechanical Fundamentals" course based on the backward design model[2].

2 Conceptual Framework

2.1 Instructional Design

Instructional design, also referred to as instructional systems design, is a systematic approach employed by designers to conceptualize and plan various components of the teaching process, including content, organization, strategies, and methods, tailored to curriculum standards and learner characteristics[3]. It typically encompasses three phases: determining content, executing teaching activities, and conducting evaluations. As an indispensable component of educational practice, instructional design is dedicated to addressing teaching challenges through systematic methodologies, aiming at optimizing educational outcomes[4]. Its appropriateness directly influences the caliber of talent nurtured and the overall teaching effectiveness.

2.2 Holistic Unit Teaching

Holistic unit teaching, an emerging pedagogical format, takes a bird's eye view of the entire unit, orchestrating teaching elements through a clear pathway, systematically mapping out unit knowledge, and synthesizing instructional plans. This approach facilitates learners' profound comprehension of subject matter, advancement of discipline-specific capabilities, and holistic personal growth[5]. It emphasizes the parity of theory and practice, the interconnectedness of unit knowledge, and individual development. By systematizing and structuring fragmented knowledge, it enhances interactivity between sessions and units, catalyzing cognitive leaps among learners.

2.3 Reverse Instructional Design

The concept of "backward curriculum design" was explicitly articulated by two American educational theorists, Grant Wiggins and Jay McTighe, advocating a reverse thinking approach that proceeds from objectives to assessment, and finally to instructional activities[6]. Under this paradigm, students' learning becomes purposeful and driven, representing a profound form of self-construction. By compelling output to drive input, and evaluating input quality through output outcomes, students' minds function as central processing units. The defining characteristic of backward design is its "beginning with the end in mind" design logic, as illustrated in Figure 1. This involves starting with the ultimate instructional goals and desired student learning outcomes, subsequently identifying credible evidence to substantiate that students have mastered the knowledge acquired and achieved a level of understanding. Finally, appropriate teaching methods or instructional activities are selected to accomplish these objectives[7]. This approach ensures that every teaching activity is directly aligned with intended learning outcomes, enhancing the relevance and effectiveness of educational experiences. The following will design teaching activities based on the three phases of backward design.

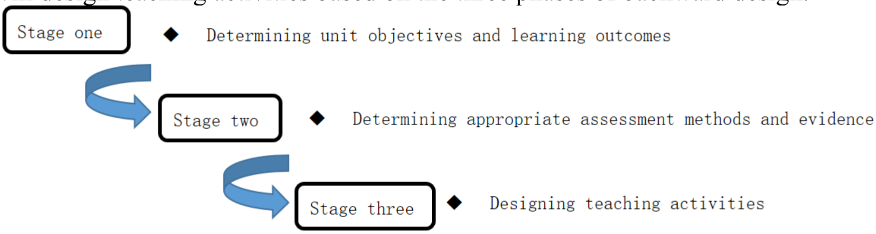


Fig. 1. The three phases of backward instructional design.

3 Three Phases of Backward Instructional Design

3.1 Phase One: Determining Unit Objectives and Learning Outcomes

Knowledge Objectives.

(1) Understand the working principle, types, characteristics, and applications of chain drives;

(2) Calculate the average transmission ratio of chain drives;

(3) Master the structure of roller chains and the assembly relationships of each component.

Competency Objectives.

(1) Through observing chain drives, improve the abilities to observe things and summarize issues;

(2) Improving hands-on operational skills through the disassembly and reassembly of chains.

Literacy Objectives.

(1) Experiencing that mechanics are everywhere in life.";

(2) Narrating the origins of chain drives, enhancing a sense of national pride.

3.2 Phase two: Determining Appropriate Assessment Methods and Evidence

Performance Tasks.

By comparing belt drives, understand the similarities and differences in internal principles and external structures; Through role-playing, comprehend the working principle of chain drives; Regarding the shortcomings of belt drives, articulate the advantages and disadvantages of chain drives; Complete calculations for chain drive ratio exercises; Disassemble and assemble chains; Identify chain drives in everyday life.

Evaluation Criteria.

As demonstrated in Table 1, evaluations are conducted to rate students' in-class performance.

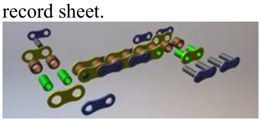
Table 1. Classroom evaluation.

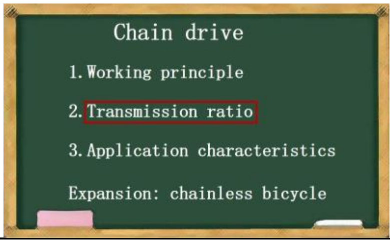
Evaluation criteria	Evaluation dimensions			Self-assessment	Peer assessment	Instructor assessment
Student classroom engagement	Actively raises hand to answer questions, demonstrates independent thinking (15 points)	Occasionally raises hand to answer questions, exhibits less independent thinking (10 points)	Rarely speaks up, does not share personal views (6 points)			
Group collaboration	Works together harmoniously and cooperatively (15 points)	Average cooperation (10 points)	Poor at collaborating (6 points)			
Completion of mind map	Completed (20 points)	Average (12 points)	Not completed (6 points)			
Disassemble the chain and fill out the practice log sheet.	Able to disassemble, identify components, and complete practical record sheet (15 points)	Struggles with disassembly and incomplete practical record sheet (10 points)	Reluctant to engage in practical work or inaccurate answers on record sheet (6 points)			
Classroom emotional attitude	Consistently enthusiastic and engaged (20 points)	Average (12 points)	Uninterested, perfunctory attitude (6 points)			
Subtotal:						
Total (Instructor's comments x 40% + self-assessment x 30% + peer assessment x 30%)						

3.3 Phase Three: Designing Instructional Activities

"This is an era of diversity, one that underscores the very essence of human development. In this context, educational practices predominantly adopt a multi-faceted pedagogy. Methods such as task-based learning, problem-oriented instruction, and heuristic teaching approaches are utilized. Such methodologies facilitate differentiated instruction, catering to individual student needs, and promoting their comprehensive development[8]. "Diversified teaching methodology" involves using a variety of teaching strategies and resources to cater to the different learning styles and needs of students, aiming to enhance engagement and understanding[9]. "Understanding learner status is key to effective teaching, Through questionnaire surveys, it was found that most students lack familiarity with chain drive principles, features, and applications. Hence, varied teaching methods are needed to address diverse student needs, resulting in the instructional activities detailed in Table 2.

Table 2. Instructional process.

Teaching segment	Teacher's activities	Student activities	Intended design
Introduction	1. Review related knowledge of belt drives to lay a foundation for learning about chain drives. 2. Introduce new lessons with a video example of chain drives.	1. Respond to questions on belt drive knowledge points. 2. Watch a video of chain drive examples in real-life production and think about where they have seen chain drives before.	Enrich students' understanding of production and life, naturally transitioning into the new lesson.
New knowledge	Point 1: chain drive working principle employ role-playing, inviting six students to act as the chain and two others to play the sprockets.	Simulate the working principle of chain drives through role-playing.	Cater to vocational students' kinesthetic learning style, stimulating interest.
	Point 2: transmission ratio of chain drives (key point) Derive the transmission ratio formula by analogy with belt drives.	Discuss: does a higher transmission ratio always mean a faster bicycle speed if the bike size is the same?	Strengthening the connection with real-life applications.
New knowledge	Point 3: characteristics of chain drive applications Prompting students to consider, what are the advantages and disadvantages of chain drives in comparison to belt drives?	Engage actively in roundtable discussions, reporting group findings.	Guiding students to leverage their strengths and mitigate their weaknesses.
	Point 4: structure of roller chains (difficult point) Utilizing AR technology to assist students in understanding the structure of roller chains.	Students will personally disassemble and reassemble the chain, and fill out the practical record sheet. 	Embracing the philosophy of learning by doing.
Practical drills	Through the idiom "crucial moment, the chain breaks," ask students if they have experienced similar situations and how they resolved them.	Use role-playing to identify three resolution strategies.	Improve problem-solving abilities.

Expansion	Expansion 1: origin of chain drives   Expansion2: Chainless Bicycle	Brainstorming: advantages and disadvantages of chainless bicycles. 	Stimulate curiosity, fostering creativity and innovative thinking.
Summary	Guide students to organize the lesson's content using mind maps.	Draw mind maps of what was learned.	Clarify logical relationships between content.
Homework	Homework is categorized into foundational assignments, practical tasks, and extension activities.	Record assignments and complete them diligently.	Assign diverse homework to cater to individual needs.
Chalkboard design			Outline the essentials, achieve natural elegance, and highlight the key points.

After the teaching activities, we administered a post-test, hrough the comparison of pre-test and post-test data, it was found that the teaching objectives were essentially met.

4 Conclusions

Integrating diverse teaching methods with backward design yields a highly effective pedagogical model. Backward design, starting with the end in mind, clearly defines learning objectives to ensure targeted and purposeful instruction. Meanwhile, diverse teaching methodologies, including real-life case studies, Augmented Reality, physical models, heuristic teaching, and task-driven learning, cater to various cognitive styles and learning needs of students[10]. The amalgamation of these ensures that teaching activities are tightly aligned with learning goals while simultaneously sparking student interest and facilitating deep learning. Furthermore, this approach not only enhances the overall educational experience but also helps students develop critical thinking skills as they apply theoretical knowledge to practical scenarios. In conclusion, the implementation of diversified teaching methodologies met the educational objectives, leading to the majority of students acquiring knowledge about the practical applications, types, and characteristics of chain drives in everyday life. This approach significantly enhanced students' interest in the fundamentals of mechanical engineering coursework, thereby laying a solid foundation for their future academic and professional endeavors.

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