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Research on Teaching Reform Path of "Digital Integrated Circuit Design" Course under OBE Concept

Jianying Shi*

College of Electronics Information Engineering, Hebei University, Baoding 071002, Hebei, China

**Author to whom correspondence should be addressed.*

Abstract: Digital integrated circuit design serves as a crucial required course for students majoring in electronic science and technology. This subject combines theoretical knowledge with practical applications, playing a key role in establishing a strong foundation for students' academic and career growth. Guided by the OBE concept, the reform of digital integrated circuit design aims to transcend traditional limitations, explore more efficient and high-quality teaching methods, and cultivate outstanding talents according to predefined goals, enabling them to meet job market demands and adapt to industry changes. To enhance the training model for professional talents in electronic science and technology and support the long-term development and planning of students, this approach achieves multiple objectives simultaneously. Consequently, this paper explores the essence of the OBE concept and provides an in-depth analysis of the current state and potential reform directions for the digital integrated circuit design course, aiming to offer valuable insights for educators on the front lines.

Keywords: OBE concept; Digital integrated circuit design; Courses; Teaching reform

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1. Introduction

Exploring the teaching reform approach for the "Digital Integrated Circuit Design" course based on the OBE concept holds significant importance at present. On one hand, the conventional teaching model faces certain challenges, such as overemphasizing theory at the expense of practice and a disconnect between educational goals and industry demands, making it difficult to fulfill the requirements for IC design talent in the modern era. On the other hand, the OBE framework offers fresh perspectives and strategies for curriculum reform, which can enhance teaching quality and foster innovative talents aligned with industrial advancements. This paper investigates the detailed pathways for reforming the teaching of the "Digital Integrated Circuit Design" course under the OBE concept, aiming to guide the reform of related courses. The focus is on the abilities and qualities students are expected to attain ultimately, conducting comprehensive design and optimization of the course instruction accordingly.

2. Overview of the OBE concept connotation

The OBE concept represents an innovative educational framework in today's context, with a primary focus on student-centered learning outcomes. It emphasizes that education should ultimately facilitate students' growth and enhancement, whether in terms of theoretical knowledge advancement or the ability to apply such knowledge to solve problems, both of which are regarded as indicators of success [1]. From the author's perspective, the OBE concept underscores the significance of outcomes, which is reflected throughout the design, execution, and assessment of teaching activities. This approach places greater emphasis on cultivating students' skills and accomplishments. In other words, guided by this concept, teaching reforms should clearly define specific course objectives and anticipated outcomes. Only by meticulously addressing every aspect of teaching can we genuinely enhance the effectiveness of a course or activity. Consequently, educators should also embrace and implement the OBE concept, prioritizing students and focusing on results. They should pay attention to students' thinking and exploration processes during theoretical learning, as well as their learning and practical exploration in hands-on activities, thereby achieving the educational goal of maximizing efficiency with minimal effort [2].

3. Teaching status of the "Digital Integrated Circuit Design" course

As an essential course for students majoring in electronics and information technology, Digital Integrated Circuit Design emphasizes the development of students' skills in IC design, problem-solving, and project advancement. However, numerous challenges persist in teaching this subject. Regarding content, the rapid evolution of integrated circuit technology continually introduces new techniques and processes, which necessitate frequent updates to instructional materials. Conversely, university research in this domain lags, with some institutions failing to align their curricula and resources with industry trends. This discrepancy creates a significant gap between students' acquired knowledge and industrial requirements, highlighting the need for enhancement and expansion [3]. In terms of format, since digital integrated circuit design combines theoretical and practical elements, current higher education often lacks sufficient hands-on training and project management experience. While certain courses incorporate experimental components, these typically focus on verification rather than fostering broader student competencies through diverse experimental activities. Students follow the procedural steps outlined in the experimental guidelines, focusing solely on completing predefined tasks. This lack of deeper exploration and independent design within the experimental content does not align with the objectives of comprehensive quality education and training in the modern era. Regarding teaching evaluation, many instructors still primarily rely on final exam scores as the key assessment criterion, emphasizing theoretical knowledge over practical skills. Consequently, it is challenging to thoroughly assess students' practical abilities, innovative thinking, and teamwork capabilities [4]. Additionally, the low emphasis placed on evaluating students' performance in regular experimental courses, their involvement, and contributions during project design can lead to students undervaluing the development of practical skills. This approach is detrimental to students' future employment prospects or entrepreneurial endeavors and hinders the growth of their overall competence and core competitiveness. Further research and optimization are necessary to address these issues.

4. The OBE concept of "Digital Integrated Circuit Design" course construction principles

4.1. Outcome orientation is clear and definite as a goal

Curriculum goals are established with a strong focus on the type of talent being developed, closely aligning with both training aims and industry demands. This alignment enables a targeted adjustment of the teaching plan. More specifically, the institution should conduct an in-depth analysis of the integrated circuit sector's expectations for digital integrated circuit design specialists, particularly concerning their knowledge, skills, and overall qualifications. It is essential to evaluate whether students need to acquire a solid understanding of digital circuit fundamentals and develop competencies in chip design and verification [5]. These requirements should then be translated into precise, assessable, and stimulating learning objectives for the curriculum. Furthermore, these objectives must be effectively communicated to students, ensuring they are aware of the learning path and anticipated results from the outset of the course.

4.2. The principle of student-centeredness runs through all along

In the context of curriculum reform, it is crucial to take into account the individual differences and learning requirements of students while implementing a variety of teaching approaches and resources. For students who lack a strong theoretical foundation, additional explanations and guidance on fundamental concepts should be offered. Conversely, for those with advanced practical skills, extended and more challenging hands-on projects can be introduced to cater to their advanced learning aspirations. It is also essential to motivate students to actively engage in classroom discussions, project-based learning, and other interactive activities, fostering their abilities in self-directed learning, teamwork, and problem-solving [6]. Particularly in collaborative group projects, students are encouraged to leverage their unique strengths and collectively accomplish project objectives, thereby enhancing their collaboration and communication competencies. This approach aligns well with the operational training and practical application demands of digital integrated circuit design and serves as a key foundation for nurturing application-focused talent.

4.3. The principle of reverse design guides the construction of course content

In accordance with the anticipated learning objectives, reverse-engineer the planning of course content and teaching activities. Initially, establish the level of digital integrated circuit design proficiency that students should achieve by the time they graduate. Then, work backward to identify the knowledge and skills that need to be imparted at each stage of the course. For instance, if students are expected to possess the capability to design chips for complex digital systems, the curriculum should begin with fundamental digital logic gates and progressively advance to combinational logic circuits, sequential logic circuits, and digital system design, thereby constructing a knowledge framework that evolves from basic to advanced concepts. Additionally, real-world industry examples should be incorporated into the instructional material to allow students to engage with authentic engineering challenges and solutions, thereby strengthening their comprehension and practical application of the knowledge [7].

4.4. Continuous improvement lays the foundation for the improvement of curriculum quality

Develop a multi-faceted curriculum assessment framework that incorporates various elements such as student assignments, examination grades, project outcomes, and class participation to holistically assess student learning outcomes. Consistently gather input from both students and industry experts, identifying challenges within the teaching process. Based on this feedback, promptly revise course materials, instructional strategies, and evaluation techniques to continuously enhance the quality of course delivery, ensuring alignment with desired learning objectives. For instance, if students encounter difficulties in digitally integrated circuit layout design, additional practical sessions can be introduced, and professional layout engineers from enterprises can be invited to deliver specialized lectures, aiding students in strengthening their skills in this domain [8]. Through these measures, the digitally integrated circuit design course remains responsive to industry advancements and student requirements, fostering highly competent designers who meet market demands.

5. Teaching reform path of "Digital IC Design" course under the OBE concept

5.1. Reconstructing curriculum, teaching and personnel training objectives

The learning goals of digital integrated circuit design courses are intrinsically linked to the talent development objectives of relevant majors, aligning with the transformation and growth needs of associated industries to jointly drive efficient and high-quality progress. Consequently, educational institutions should proactively research to comprehend the precise demands for knowledge, skills, and qualities required in digital integrated circuit design professionals. Particularly, given the current rise of artificial intelligence and the Internet of Things, specialized application domains and evolving directions necessitate optimizing talent cultivation strategies. Thus, the course's teaching objective is defined as equipping students with a solid understanding of the fundamental theories and methodologies of digital integrated circuit design, proficiency in mainstream design tools, and the ability to design, simulate, and verify digital integrated circuits based on practical application requirements. Additionally, emphasis should be placed on fostering students' innovative thinking and collaborative teamwork abilities to meet industry project development needs and prepare them for future employment in professional roles. In the curriculum reform framework guided by the OBE concept, considering the varying foundations and capabilities among students, course design topics are structured hierarchically into three levels: "basic, intermediate, and advanced." This approach encourages students' design thinking to expand fully while enabling them to independently complete tasks within specified timeframes. Moreover, distinct criteria and expectations are established for students at different levels, ensuring personalized instruction tailored to individual aptitudes. The design principles can be summarized as follows: the outcomes of the design should encompass the principles of digital integrated circuit design, which necessitates a thorough comprehension and proficiency in fundamental theoretical knowledge. The design process should also integrate practical engineering applications, connecting to everyday life and real-world work scenarios. Furthermore, it should involve various practical activities, such as encouraging participation in innovation and entrepreneurship competitions, as well as scientific research group activities, to establish a comprehensive and cohesive educational framework [9]. Additionally, adjustments have been made to both the curriculum construction objectives and talent cultivation goals, aligning with the teaching content and methods. This ensures that students genuinely take on the primary role, enabling flexible collaboration and teamwork, and collectively completing the professional training program to solidify a strong foundation for their future career advancement.

5.2. Attach importance to consolidating students' professional foundation

Guided by the OBE concept, apart from setting clear objectives and refining course activities, emphasis should also be placed on nurturing students' subjective awareness, self-directed learning capabilities, and innovative thinking. Consequently, this approach underscores the dual nature of the "digital integrated circuit design" course—being both theoretical and practical [10]. The principles of digital logic gates, combinational logic circuits, and sequential logic circuits are elucidated in detail. When necessary, supplementary tools such as micro-class videos, presentation slides, and project exercises can be utilized to enhance students' comprehension. Additionally, a deeper exploration of semiconductor devices and amplifying circuits is essential, enabling students to grasp the operational mechanisms of fundamental components within digital integrated circuits. This not only stimulates their interest in learning but also strengthens their command of foundational knowledge. Specifically, beginning with system requirement analysis, the curriculum integrates knowledge areas such as computer architecture and communication principles. During the logical design phase, it incorporates concepts from digital circuit fundamentals and algorithm design. In the physical design stage, it connects with subjects like semiconductor physics and integrated circuit fabrication processes. By assisting students in constructing a comprehensive knowledge framework, they can effectively apply their understanding to solve real-world problems. Besides the course itself, we will arrange practical activities related to specific projects, organize group-based research, innovation, and entrepreneurship competitions, guide students to revisit logical operations and simplification techniques from digital circuit fundamentals, and review device characteristics and processes in semiconductor physics. This approach reinforces students' understanding and retention of foundational knowledge, preventing forgetting that may result from prolonged disuse. Such efforts provide robust support for subsequent course content [11–13]. These activities aim to strike a balance between theory and practice, promote independent and efficient learning of basic theories, and strengthen knowledge retention through experimental practice. The two aspects complement each other, forming a high-quality digital integrated circuit design curriculum system that merits further exploration and dedication of time.

5.3. Pay attention to the cultivation of digital literacy

By leveraging the OBE concept to innovate the teaching model for digital integrated circuit design, it is crucial to enhance students' digital literacy and learning capabilities. This ensures they can proficiently use various digital integrated circuit design tools, providing a strong foundation for future employment, innovation, and entrepreneurship. Specifically, course instruction should incorporate relevant software training and practical project exercises, enabling students to become adept at the operational processes of design tools. They should also be capable of utilizing these tools to complete circuit design, simulation, and verification tasks, thereby genuinely broadening their academic perspectives and reinforcing their practical skills [14]. Moreover, as artificial intelligence technology increasingly integrates into integrated circuit design, introducing AI-based design aids and methods can help cultivate students' ability to apply emerging technologies. Following simulation experiments, students can be guided to analyze the resulting data, assess whether circuit performance aligns with design requirements, identify existing issues, and propose improvement strategies [15]. Simultaneously, students can be taught to use data analysis software to enhance the efficiency and accuracy of data processing and analysis. Overall, fostering college students' proficiency in digital technology application and data processing, and analysis is essential. Strengthening their overall quality and competence as the ultimate goal involves optimizing and refining the teaching process and content, an area worthy of deeper exploration. Additionally, the application of innovative models such as the flipped classroom, blended teaching, virtual simulation experiments, and VR/AR technologies represents a potential direction for future reforms in digital integrated circuit design courses.

6. Conclusion

Overall, curriculum teaching reform is not merely a simple slogan; it also demands that educators take action, starting with themselves, and focus on minor details while redefining the goals and activities of the curriculum. This process still has a long journey ahead. By concentrating on the optimization and reform of the digital integrated circuit design curriculum, and per the development objectives of colleges and universities for the next phase, we can identify distinctive features and emerging directions. We will redesign the approaches and pathways for curriculum construction, ultimately establishing a unique, high-quality professional curriculum teaching system within higher education institutions—an area deserving of our thorough investigation and practical implementation. Looking forward, it will be essential to refine, adapt, and modernize the digital IC design course based on the specific planning circumstances of certain schools and specialized fields. Through these efforts, we can lay the groundwork for cultivating top-tier, high-caliber talents and elevate higher education to new heights.

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