A Study on Integrating Bloom's Taxonomy With AI Learning Partners to Enhance Self-Directed Learning in Visual Communication Drawing Courses

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Abstract
In the aftermath of technological advancements and the global pandemic, the rapid development of Artificial Intelligence (AI) has significantly impacted people's lives and learning experiences. However, post-pandemic, students' learning patterns in physical classrooms have shown noticeable differences from pre-pandemic times. Therefore, this study delves into the new challenges faced by teachers and students in a design drawing course, attempting to innovate by integrating Bloom's Educational Taxonomy Model to enhance students' self-directed learning. The research focuses on the second-year Visual Communication Drawing course in a Taiwanese design department, emphasizing the drawing of products and explanatory diagrams incorporating perspective principles. Applying Bloom's Taxonomy, the study clarifies the roles of teachers, AI, and students in the instructional environment, guiding students in selecting appropriate tools and techniques to cultivate core competencies such as "problem-solving" and "self-directed learning." In the pre-planning phase, teachers and AI learning partners provide guidance on drawing directions and guide students in problem exploration. The design verification phase includes conceptual development and verification of drawing implementation, while the effectiveness assessment phase emphasizes presenting project outcomes and cultivating students' evaluation and reflective abilities. The anticipated outcomes of this research not only include enhancing students' learning motivation and proactivity but also cultivating their awareness of the living environment. Ultimately, the research aims to strengthen students' graphic expression skills, serving as a valuable reference for design education and curriculum planning in related fields.

Keywords: Bloom's Educational Taxonomy Model, AI Learning Partners, Self-Directed Learning

Introduction

With technological advancements and the disruptions caused by a global pandemic, artificial intelligence has dramatically reshaped the landscape of education. As we emerge from the challenges posed by the pandemic, the learning environment in physical classrooms has witnessed significant transformations. The methods and approaches to learning have evolved, becoming distinct from those prevalent before the pandemic. A crucial concern now is ensuring that students understand their evolving role in this new educational paradigm. Without a clear sense of agency and control over their learning processes, students may harbor fears of being displaced by technology or overshadowed in a rapidly changing world.

In response to these shifts, our research focuses on the novel challenges confronting both educators and learners. We aim to classify these challenges utilizing the structured approach of Bloom's Taxonomy, which serves as a tool to elucidate the evolving roles of teachers, artificial intelligence, and students within the educational setting. By doing so, we provide a roadmap for students to navigate the selection of tools and techniques that best suit their learning needs. Our goal is to foster the development of essential professional skills such as problem-solving, self-direction, and other core competencies that are vital in today's world.

Further, we are exploring innovative ways to leverage Bloom's educational taxonomy in enhancing self-directed learning among students. This involves adapting teaching strategies that not only impart knowledge but also empower students to take ownership of their educational journeys. By integrating AI as a supportive tool rather than a substitute, we aim to enhance the educational experience, making it more interactive, personalized, and attuned to the needs of each student.

This holistic approach not only addresses the immediate challenges posed by the integration of AI in education but also paves the way for developing a resilient educational framework that supports continuous learning and adaptation in an ever-evolving global landscape. Through these efforts, we strive to equip students with the skills and confidence needed to thrive in the future, whatever it may hold.

Literature Review

(1) Bloom's Taxonomy Levels

Developed by Benjamin Bloom and his colleagues in 1956, Bloom's taxonomy has been a cornerstone in educational theory for decades（Bloom et al., 1956）. Bloom's taxonomy divides educational goals into three areas: cognitive, affective, and psychomotor. The cognitive domain, which is most commonly applied and centers on intellectual abilities, is frequently represented as a pyramid with six tiers: knowledge, comprehension, application, analysis, synthesis, and evaluation. This pyramid suggests that advanced cognitive abilities are developed through the foundation of more basic skills. Later, in 2001, scholars including Anderson revised the educational objectives classification system (Anderson & Krathwohl, 2001). The primary difference between the old and new versions is the division of the original single dimension into "Knowledge Dimension" and "Cognitive Process Dimension." The former assists teachers in distinguishing "what to teach," while the latter displays the levels of thinking that students demonstrate during the learning process. Therefore, within the "Cognitive Process Dimension," the levels of student cognitive thinking progress from low to high, namely remembering, understanding, applying, analyzing, evaluating, and creating.

According to Bloom's taxonomy of cognitive domains, the self-study that students undertake before or after class involves lower levels of cognition, such as remembering and understanding. This primarily involves learning the basic content of a subject through video explanations. In contrast, higher-level cognitive learning occurs during class, including application, analysis, and evaluation (Francl, 2014). Consequently, the role of teachers in classroom learning shifts from being instructors to facilitators of learning and guides in problem-solving. Through classroom discussions, the design of collaborative learning activities, individualized guidance, and various strategies that promote deep reflection, teachers help students engage in higher-level cognitive behaviors, particularly in application, analysis, and evaluation (Spencer, Wolf, & Sams, 2011). As shown in the figure1. Higher-order thinking skills (HOTS) are extensively acknowledged as fundamental competencies for outstanding individuals in the 21st century (Orakci, 2023; Vincent-Lancrin et al., 2019).

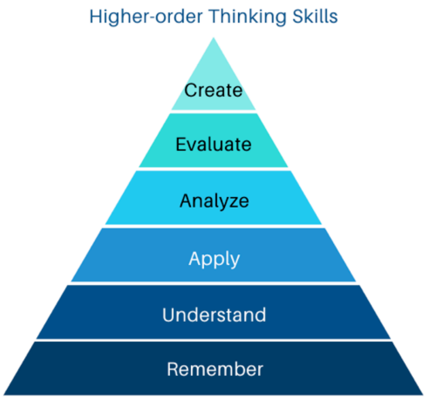

Figure 1: Bloom's Taxonomy Levels

(2) Self-Directed Learning

The philosophical foundation of self-directed learning is deeply rooted in Abraham Maslow's notion of self-actualization (1954) and Carl Rogers' experiential learning (1969), as further elaborated by Hsiao, Hci-chi and Tsung-Lung Chen (1996). Maslow posited that through self, individuals can transform reality and gain insights into their own motivations. Rogers expanded upon Maslow’s ideas, asserting that the self is the driving force behind an individual's actions, creativity, and personality development.

Lucy Guglielmino (1977), drawing from the research of Malcolm Knowles, Peter Moule, and Allen Tough, distilled a definition of self-directed learning. She portrayed self-directed learners as proactive, independent, and patient, bearing a deep sense of responsibility towards their learning. These learners are characterized by their resilience to challenges, ability for self-discipline, high curiosity, strong desire to learn, capacity for self-affirmation, proficiency in basic learning skills, effective time management, and enjoyment in learning with a clear goal orientation. She regarded self-directed learning as a distinct capability.

Furthermore, Rogers (1983) viewed self-directed learning as the freedom to learn and choose independently. Spear and Mocker (1984) observed that self-directed learning showcases a learner's autonomy, especially their capacity to take primary responsibility for their learning, choosing their educational objectives and the significance of their studies. Carol Kasworm (1988) argued that self-directed learning must balance external definitions with internal perceptions of self, considering both cognitive processes and the frameworks of human psychological development. This approach acknowledges the learner’s agency and emphasizes a comprehensive understanding of their educational journey.

(3) Visual Communication Drawing

Visual Communication Drawing plays a pivotal role in effectively conveying both quantitative and qualitative information through various visualization techniques. The goal of data visualization is to determine the most appropriate methods for different contexts to enhance understanding and communication (Romero-Organvidez et al., 2024). Architectural drawing, particularly freehand drawing, is crucial for identifying and selecting valuable information, whether it is derived from a physical site or conceptualization. This practice allows for the representation of complex ideas and spatial concepts in a tangible format (Chao, V. L., & Grela, M. Rodríguez, 2023). Freehand perspective drawing is especially effective in communicating the illusion of three-dimensional objects or spaces. These are often intangible and difficult to express using more restrictive, standardized techniques such as multi-view orthographic projection. Practicing freehand drawing aids creatives in visualizing and thinking about architecture, thus supporting the design process (Herdert, 1988).

In the context of Taiwan, the Visual Communication Drawing course emphasizes the importance of drawing products and diagrams based on perspective principles. This course highlights the critical role of concept generation, beginning with customer needs and specifications and concluding with various product alternatives. According to MICAL (NOBEL, 2013), concept generation is an essential step in the engineering design process.The product representation techniques course is dedicated to visualizing concepts, examining the development of concept proposals during the product design phase. Our research explores the dynamics among teachers, students, and AI, particularly following the integration of Bloom's Taxonomy Levels. We are assessing new challenges faced by teachers and students and exploring how Bloom's Educational Taxonomy can enhance self-directed learning among students.

By integrating these various perspectives and techniques, Visual Communication Drawing proves to be an indispensable tool in the educational and professional development of students in design fields. It not only enhances their ability to visualize and communicate complex concepts but also fosters creativity, innovation, and independent learning skills.

Methodology

(1) Bloom's Taxonomy Levels and the Relationship Diagram With Teachers, Students, and AI

We have meticulously defined the roles of teachers, AI, and students to nurture the development of crucial skills like problem-solving and self-directed learning. Our study delves into the synergistic interactions among teachers, students, and AI within the educational framework, aiming to enhance the educational process through collaborative efforts. By integrating technology thoughtfully, we ensure that it augments student learning without overwhelming it.

Employing Bloom's Taxonomy, we delineate the distinct functions within our educational ecosystem: teachers serve as mentors, guiding students through structured learning activities and providing valuable feedback; students pursue learning autonomously, taking ownership of their educational journey and engaging in self-directed tasks; and AI provides consistent support throughout the learning journey, acting as a tutor, tutee, and tool. The AI assists students in generating ideas, visualizing concepts, and refining their work, thereby fostering a more interactive and effective learning environment.

As illustrated in Figure 2, this tripartite model creates a dynamic and flexible learning environment where each component contributes uniquely to the students' educational experience. Teachers facilitate critical thinking and problem-solving skills, AI offers personalized and adaptive learning experiences, and students develop independence and creativity. This collaborative approach not only enhances the learning process but also prepares students to meet the demands of the ever-evolving job market, equipping them with the skills necessary to thrive in a technology-driven world.

Furthermore, as we refine this teaching approach based on continuous feedback from students and educators, we anticipate even greater improvements in learning outcomes. The integration of AI in education represents a significant advancement, providing opportunities for more tailored and effective teaching methods. This innovative approach has the potential to transform traditional educational practices, making learning more engaging, interactive, and effective for students at all levels.

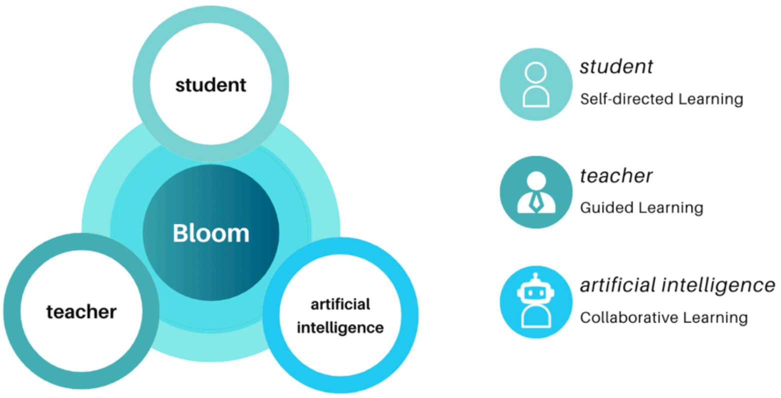

Figure 2: Bloom's Taxonomy Levels and the Relationship Diagram with Teachers, Students, and AI

(2) Bloom's Taxonomy Levels and Their Relationship With AI

To enhance the learning experience with AI and deliver tailored content, we incorporate three specialized roles for AI: Tutor, Tutee, and Tool. Each role distinctly enriches the educational journey by contributing uniquely to the overall learning process.

As a Tutor (covering levels 1 to 3), AI assumes the role of an instructor, offering students guidance and expertise, much like a traditional teacher. This role involves providing explanations, answering questions, and facilitating the understanding of fundamental concepts. AI tutors can personalize instruction based on individual student needs, adapting to their learning pace and style. This personalized guidance helps students grasp essential knowledge more effectively and build a strong foundation for further learning.

In the capacity of a Tutee (encompassing levels 4 and 5), AI engages with students by undertaking tasks assigned by them, facilitating the construction of knowledge. In this role, AI acts as a learning companion, working alongside students to solve problems, complete assignments, and explore new ideas. This collaborative approach encourages students to take ownership of their learning, fostering critical thinking and problem-solving skills. By interacting with AI as a peer, students can experiment with different strategies, receive immediate feedback, and refine their understanding through iterative learning.

At its most advanced stage, as a Tool, AI transforms students' concepts into reality, actively generating content. This role allows AI to collaborate closely with students, enhancing focus and efficiency by equitably distributing the workload. As a tool, AI supports the creative process, helping students visualize their ideas, develop prototypes, and iterate on their designs. This hands-on interaction with AI tools empowers students to bring their concepts to life, bridging the gap between theoretical knowledge and practical application.

This multi-faceted integration of AI into the educational process, as illustrated in Figure 3, creates a dynamic and interactive learning environment. The synergy between human instructors, AI companions, and students fosters a rich, immersive educational experience that adapts to the needs of each learner. By leveraging AI in these distinct roles, we can enhance student engagement, promote deeper understanding, and cultivate essential skills for the future.

Moreover, as we continue to refine and expand this approach based on ongoing feedback from students and educators, we anticipate further improvements in learning outcomes. The integration of AI in education not only provides innovative teaching methods but also prepares students to navigate and excel in a technology-driven world. This progressive approach to education has the potential to revolutionize traditional learning models, making education more accessible, personalized, and effective for learners of all ages and backgrounds.

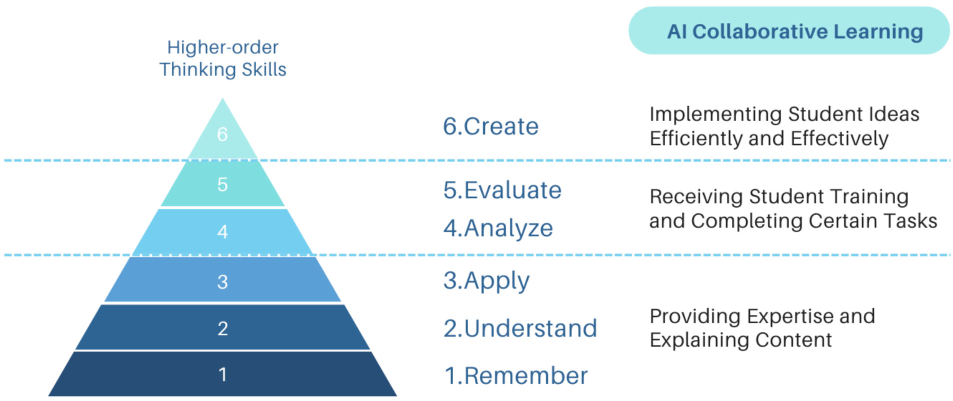

Figure 3: AI Tasks at Each Stage

Curriculum Design

This describes a traditional product design process, where our course focuses primarily on product representation techniques. The most critical step in the product development process is concept generation, which is when the product development team comes up with ideas. Concepts can be defined as preliminary descriptions of the product's technology, workings, and form, or as concise descriptions of how the product meets customer needs, as Ulrich and Eppinger pointed out in 2012. In the new product development phase, concept presentations typically emphasize the design team's visualization of the product concept proposals, and the importance of visualization in industrial product design is well understood and widely researched. Early studies, like those by Goel in 1995 and Goldschmidt in 1991, explored the role of visuals in the thinking processes of designers.

Our study focuses on the second-year Visual Communication Drawing course at Asia University in Taiwan, which emphasizes drawing products and diagrams based on perspective principles. The course highlights the critical role of concept generation, starting with customer needs and specifications and concluding with various product alternatives. According to MICAL (NOBEL, 2013), this step is essential in the engineering design process.

Combining Bloom's Taxonomy with self-directed learning methods, the course design integrates teacher-led instruction, AI-assisted learning, and student self-learning. This approach emphasizes developing essential self-learning skills such as task awareness, setting learning goals, strategizing learning methods, and practicing reflection and adjustment.

Given that artificial intelligence is being introduced to the design drawing classroom for the first time, the initial approach involves traditional teacher-led instruction. This method utilizes the functional structure deployment of product design to help students comprehend the internal and external configurations of products. Additionally, worksheets are provided to assist students in setting standards and planning their progress. The basic process is illustrated in Figure 4.

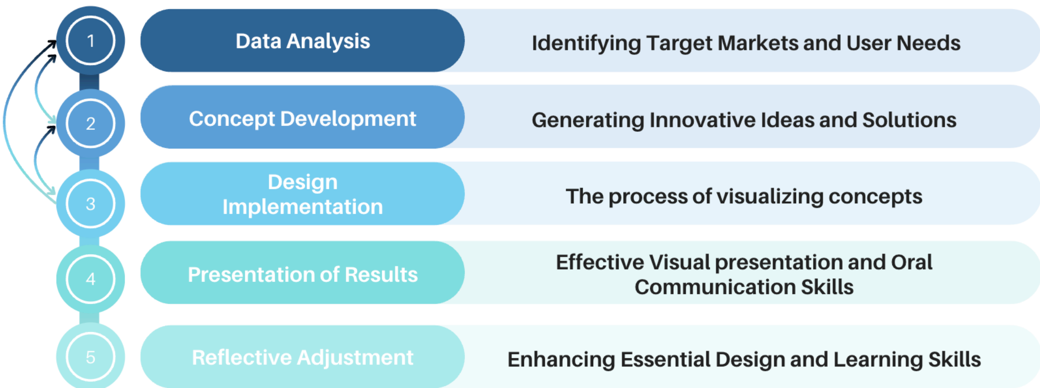

Figure 4: The basic process

In this course, ChatGPT and Microsoft Bing Image Creator are the primary generation tools used within a self-directed learning framework. Through a blend of student self-learning, AI-assisted learning, and teacher-guided instruction, students collaboratively complete course assignments. Initially, the teacher conducts a session to analyze the tasks, guiding students not only to understand AI but also to grasp relevant product design knowledge.

Following this, students use ChatGPT or Bing AI to generate prompts and Bing Image Creator to produce images. Once the images are generated, students proceed with selection and iteration steps, which constitute the debugging phase. This step requires students to make judgments based on human-centered design principles as advocated by Donald A. Norman, considering ergonomics and usability.

Gradually, students develop a rapport with their AI partners, resulting in the creation of usable product images. Finally, students engage in hand-drawing practice based on the generated images. Below are the main steps in the image generation process.

AI Image Generation Exercise: Coffee Machine Design

The coffee machine design exercise through AI image generation is structured into three meticulously planned phases:

1. Functional Structure Deployment Phase: In this initial phase, the team conducts a comprehensive analysis of the product's function, examines the basic structure, explores configuration methods, and begins shaping the form along with other preparatory steps. This foundational stage sets the stage for detailed design work.
2. Prompt Phase: Guided by the human-centered design principles championed by Donald A. Norman, a renowned scholar in cognitive science and human factors engineering, this phase focuses on the key concepts of discoverability and understandability. By adhering to these principles, prompts are meticulously crafted to steer the design process, ensuring clarity and ease of user interaction.
3. Concept Proposal and Drawing Phase: Following the generation of AI-assisted product images, the process advances by systematically observing the generated images. This observation leads to a phase of questioning, selecting, and iterating, which refines the design. Subsequently, the detailed drawings of the coffee machine and its explanatory diagrams are initiated. These visuals are meticulously crafted to adhere to strict design principles: they must comply with perspective drawing principles, uphold usability standards, and resonate with the designated style, blending functionality with aesthetic appeal.

Each phase is designed to build upon the last, ensuring a cohesive and thorough approach to designing a user-friendly and visually appealing coffee machine.

Result & Conclusions

The paired samples t-test analysis revealed a significant difference in the mean scores of design development between AI-assisted instruction and traditional instruction, t (9.951), $p<.001$. The design development score with AI assistance was significantly higher than the score without AI assistance. As shown in the table 1.

	Mean (Standard Deviation)		df	t-value	p
	Form Development Ability in Traditional Teaching	Form Development Ability in AI-Integrated Teaching			
Score	66.18（9.989）	76.77（9.167）	55	9.951	<.001

Table 1: Dependent samples T-test

This study conducted a reliability analysis on a 17-item scale for measuring the effectiveness of AI in performance technique learning, with a test value of 3.5. In the school's teaching evaluation, the learning effectiveness of the course was rated 4.64 points, showing that students are positive about their learning effectiveness.

Compared to traditional teaching methods, initially introducing AI learning partners requires students to spend some time building a rapport with the AI. Under structured guidance from teachers, students can quickly adapt and harness the benefits of AI-assisted learning, thereby improving the quality and efficiency of their learning. During the concept generation phase, AI helps students produce more ideas, enhancing efficiency, precision in form comprehension, and visualization capabilities. The students' results are shown in Figure 5.

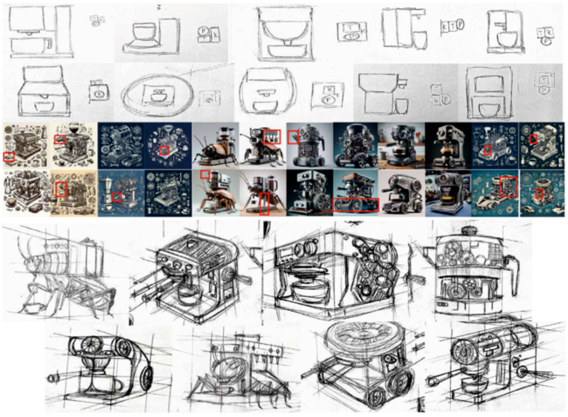
Figure 5: student course outcomes

To address any deficiencies that may arise from the introduction of AI in the classroom, we have established specific operation methods and processes:

1. Provide Study Sheets: These sheets will include directions for prompt word inputs, guiding students to construct sentences focusing on aspects such as shape, color, material, and surface texture. This structured approach will help students articulate their design ideas more effectively.
2. Iterative Verification: The images generated by AI are primarily based on visual art rather than dynamic analysis of actual user interaction with the product. As AI cannot fully comprehend or simulate human physical and psychological reactions, it is crucial to iterate on the visual distortions present in the AI-generated graphics. Particular attention must be given to human factors and usability to ensure the designs meet real-world needs and expectations.

By continuously refining these methods, we can ensure that the integration of AI into design education not only addresses its current limitations but also leverages its strengths to foster a more dynamic and effective learning environment.

In conclusion, integrating Bloom's Taxonomy with AI Learning Partners into a practical design course has proven to be highly effective. This innovative approach has facilitated a deeper understanding and application of design principles among students. Moving forward, we can further refine this teaching methodology based on student feedback to enhance innovation, creativity, and independence. This iterative process will significantly boost the learning potential and job market competitiveness of Taiwanese design students.

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