DACUM Approach for Integrating AI Competencies and Product Design Skills in Nigeria's TVET Programs

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ABSTRACT

The technological advancement that revolutionized the way industries operate requires reform and integration of emerging technologies skills in TVET programs worldwide. These lead to a significant skills mismatch between Nigeria's TVET programs and the skills demanded from graduates by industries. This mismatch needs urgent action to bridge the gap between job market needs and TVET programs. Industry-directed curriculum design is required to enable graduates to seemingly fit in and become employable in the industry 4.0 era. This paper aims to present a process for developing a curriculum or integration guide of AI competencies and product design skills in TVET programs in Nigeria that directly considers industry needs and expectations. DACUM (Developing a Curriculum) is a job-related assessment process that connects industry needs with educational institution programs. It was used within a two-day workshop with product designers from different industries around the Northwestern region of Nigeria. Duties, tasks, AI competencies, and product design skills were identified during the workshop. The eight primary duties include: (1) Research and analyze data, (2) Ideate concept, (3) Implement design, (4) Test and validate design, (5) Optimize design, (6) Detail and document design, (7) Present design, and (8) Collaborate with manufacturing engineers. Three to seven tasks were identified during the DACUM workshop for each of these main duties. To validate the results, a survey was conducted where product designers within industries and firms in the study area participated. The results of this study will be used to integrate AI competencies and product design skills in various TVET programs in Nigeria.

Keywords: TVET programs, graduates, product design skills, AI competencies, curriculum integration.

INTRODUCTION

Considering that the rapid advancement of technology has substantially changed industries' operational patterns worldwide, leading to the need for continuous adaptation and innovation. In recent years, the emergence of Industry 4.0 has transformed manufacturing, automation, and industrial processes through innovative technologies, interconnected systems, and data-driven decision-making (Lucy Cecilia et al., 2024). Nowadays, researchers focus on developing frameworks and strategies to integrate Industry 4.0 competencies in TVET programs for transformation and alignment with industry needs (Adnan et al., 2021; Ismail & Hassan, 2019; Jafar et al., 2020; Wickramasinghe & Wickramasinghe, 2024). At the core of this transformation is Artificial Intelligence (AI), which is restructuring how industries work by enhancing efficiency, optimizing production, facilitating intelligent automation, and AI-driven product design (Quan et al., 2023). As these technologies evolve, the demand for a skilled workforce equipped with AI competencies and product design expertise in TVET programs has risen drastically (Lim & Lee, 2024).

One of the most compelling challenges today is the changing landscape of skills demand in the world of work (Saniuk et al., 2021). Nigeria's TVET curriculum often fails to align with the rapidly evolving needs of contemporary industries, resulting in a mismatch between graduates' abilities and industry expectations (Ezekiel & Deebom, 2022). This misalignment has led to a growing skills gap, a rising unemployment rate reaching 21.9% in Q4 2022 and 18.1% in Q1 2023 (National Bureau of Statistics, 2023). This indicates how increasingly difficult it is for TVET graduates to secure employment or efficiently contribute to industrial production upon employment. To address this issue, there is an urgent need for comprehensive curriculum enhancement that integrates AI competencies and product design skills, ensuring that TVET graduates are equipped for the intricacies of contemporary manufacturing and technological revolution (Alabadan et al., 2020; Chidubem et al., 2020; Jogana et al., 2020).

Product design has become an essential element of modern industry, encompassing user experience, material selection, aesthetics, ergonomics, optimization, and sustainability considerations (Kunrath et al., 2020). Most of the TVET programs in Nigeria give less consideration to those aspects of product design. The curriculum contained little or none of these product design elements, leading to producing graduates with fewer competencies and skills in terms of designing and making a sellable product (Chidubem et al., 2020). These could be the reasons most Nigerians prefer products made in other countries, perceiving Nigerian-made products as substandard, as lamented by the director of the Standard Organization of Nigeria (Yafugborhi & Chioma, 2023).

However, in the age of AI-driven advancement, integrating intelligent systems into product design has become more significant (Hou et al., 2021). AI tools such as ChatGPT, LaMDA, DALL-E, Midjourney, Stable diffusion XL, Imagen Video, Autodesk Fusion 360, and Get3D by NVIDIA, used for generative design and predictive analytics, transform how products are conceived, developed, and improved (Patel et al., 2024). Consequently, TVET programs must equip students with the necessary skills to harness AI tools for enhanced standard product design that is ergonomically, aesthetically, and sustainably sound, enabling them to acquire entrepreneurial skills, contribute meaningfully to industry advancements, and secure self-sustainable employment.

To bridge the gap between TVET and industry demands, TVET institutions in Nigeria must adopt a future-oriented approach incorporating AI competencies and product design skills (Rosyadi et al., 2023). This integration will enhance students' employability, foster a workforce that can drive innovation, address real-world industrial challenges, and uplift Nigerian economic growth through industrial production. By aligning TVET curriculum with the evolving technological landscape, TVET programs can play a crucial role in shaping the future workforce, improving gender equality in TVET fields, and ensuring sustainable industrial growth (Adepoju et al., 2024). Hence, this paper intends to utilize the DACUM approach to explore the job profile of a product designer, AI competencies, and product design skills needed to guide the TVET stakeholders in developing and integrating AI competencies and product design skills in Nigeria's TVET programs curriculum.

METHODOLOGY

To explore the duties, tasks, product design skills, and AI competencies, a two-day DACUM workshop was conducted online with industrial product designers from furniture, plastic moldings, and metal fabrication industries and firms situated in the northwestern region of Nigeria, including Kano, Kaduna, Katsina, Jigawa, Sokoto, Kebbi, and Zamfara states. This workshop was conducted using DACUM, or "Developing A Curriculum," a traditional curriculum development approach put forth by the Ohio State University Center on Education and Training for Employment (DeOnna, 2002).To create an occupational skill profile that could be utilized for various tasks, including program planning, curriculum development, training material development, needs assessment, and more, DACUM was first proposed as an occupational analysis tool carried out by expert workers in a particular occupation. Practitioners from specific occupations collaborate with a certified DACUM facilitator on a brief committee assignment as part of the DACUM process for occupational analysis. To create a DACUM research chart, which includes a list of general areas of competence known as duties and the tasks that define those duties, these employees get together in a panel brainstorming session (Bhattarai, 2021).

According to the DACUM handbook by Norton, (1997), A DACUM committee is made up of 8–12 expert workers in a particular job position from a directly related industry, business, and organization; these experts are outstanding in their occupations, so they do not need preparation for these meetings. Facilitators guide the committee members for two days to develop the DACUM chart depicting the competency duties and tasks to perform a specific occupation. DACUM is based on three principles: job descriptions where experts are considered best to do so, competent/successful workers who perform the tasks can effectively describe them, and specific attitudes and knowledge are required to perform each task. The DACUM workshop usually starts with an orientation to inform the attendees about the DACUM process. Following (Fortuna, 1996) Steps in Table 21.

Table 2.1 DACUM process steps

Steps	**Descriptions**
Step One:	Orient the Committee to the DACUM process and their role.
Step Two:	Review the occupation. Agree on a job title and clarify the relationship of the position under study with other positions in the organization.
Step Three:	Identify duties or broad areas of responsibility.
Step Four:	Identify specific tasks performed. Specify six or more tasks that are performed in each duty area. Each task statement begins with an action verb, and emphasis is placed on selecting measurable verbs.
Step Five:	Review and reward unclear task and duty statements.
Step Six:	Rank Each Task and duty statement logically based on Criticality: Essential or most important job components.
Step Seven: .	Identify related requirements such as traits, general knowledge areas, and special equipment needed.

Demographic Data of Respondents

The demographic profile of respondents was presented in Table 2.2 to enhance contextual interpretation of the results. Variables collected include respondents' Working industry, Years of working experience, and Area of specialization. These variables were analyzed descriptively using frequencies and percentages to provide insight into the diversity and representativeness of the sample.

Table 2.2 DACUM validation participants demography

	Working industry		
S/N	**Demographic variable**	**Frequency**	**Percentage**
1	Furniture industry	8	13.1%
2	Metalwork fabrication industry	13	21.3%
3	Interior design industry	8	13.1%
4	Automotive industry	8	13.1%
5	Plastic molding industry	19	31.1%
6	Others	5	8.2%
	TOTAL	**61**	**100%**
	Years of working experience		
S/N	**Demographic variable**	**Frequency**	**Percentage**
1	5-10 years	20	32.8%

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2	11-15 years	10	16.4%
3	16-20 years	24	39.3%
4	21 and above years	7	11.5%
	TOTAL	**61**	**100%**
	Area of specialization		
S/N	**Demographic variable**	**Frequency**	**Percentage**
1	Concept Designing	7	11.5%
2	Visual designer	2	3.3%
3	Market and user research	8	13.1%
4	Product Brief	6	9.8%
5	Innovative design	6	9.8%
6	Proficiency in CAD software	13	21.3%
7	Analyzing product design requirements	6	9.8%
8	Assessing product usability and safety	1	1.6%
9	Prototypes	11	18.0%
10	Feasibility analysis	1	1.6%
	TOTAL	**61**	**100%**

DACUM workshop

In this study, a panel of 12 professionals from companies, as recommended by Bhattarai, (2021), with a focus on product design, were selected to participate in the DACUM process. The panel included four designers from the furniture industry, five from the metalwork fabrication industry, and three from the plastic molding industry, with 10 to 15 years of working experience. A two-day meeting was facilitated by two representatives from the Hydraulic Equipment Development Institute (HEDI) and Northwest University, Kano, to identify the product designers' job profile requirements from the industry point of view. The meeting began with an introduction to the DACUM process, which included the goals of the process and an overview of how the results should look. The facilitators systematically guided the participants through a brainstorming process in which the main duties, tasks, AI competencies, and product design skills necessary to perform the product design job were identified. When there were panel disputes, the facilitator instructed them to debate to achieve consensus and complete the process. One of the facilitators constantly recorded duties, task statements, relevant AI competencies, and product design skills on screen, which were displayed and visible to the participants. This process is important since it allows for rearrangement and reorganization until a more acceptable position in the order of their importance and priority is achieved (Duzguncinar, 2023).

Instrument Reliability and Validation

To validate the results of this process, a survey was conducted via an instrument developed in Google Forms and sent to an additional 61 product designers. The survey was based on a Likert rating scale from (1 = Not important, 2 = Slightly important, 3 = Moderately important, 4 = Very important, and 5 = Extremely important), asking the sampled product designers to rate the importance of duties, tasks, AI competencies, and product design skills.

To ensure the reliability and internal consistency of the survey instrument used in this study, the instruments were pilot tested, and Cronbach's alpha coefficient was calculated for each section of the questionnaire as shown in Table 2.3. A Cronbach's alpha value ranging from 0.677 to 0.916 was obtained and considered acceptable, indicating satisfactory reliability for the scale items measuring Duties, Tasks, AI competencies, and

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Product design skills. In addition, the instrument underwent expert validation by three professionals in TVET curriculum design and AI integration, whose feedback helped refine item clarity and relevance.

Table 2.3 Cronbach's alpha coefficient values for instruments reliability

S/N	Instrument constructs	Cronbach's alpha	Items
1	DUTY (A) Research and analyze data	0.677	7
2	DUTY (B) Ideate concept	0.881	7
3	DUTY (C) Implement design	0.892	5
4	DUTY (D) Test and validate design	0.897	7
5	DUTY (E) Optimize design	0.795	4
6	DUTY (F) Detail and document design	0.787	3
7	DUTY (G) Present design	0.916	7
8	DUTY (H) Collaborate with manufacturing engineers	0.895	7
9	AI utilization competencies	0.793	12
10	Product design skills	0.842	11

Response Rate and Sampling Details

The survey was finally distributed to a total of 61 participants, out of which 61 valid responses were received, yielding a response rate of 100%. This response rate was deemed adequate for inferential analysis and generalization within the context of the study.

RESULTS AND DISCUSSION

After reviewing, revising, and validating, the expert panel identified and reorganized the product designer job profile, with between 3 and 7 tasks for each duty; 42 tasks within 8 duties were identified and validated, along with 12 AI competencies and 11 product design skills. The final list of duties and tasks was organized into the DACUM chart format in Table 3.1. The list of validated AI competencies and product design skills is presented in Table 4.1 and Table 5.1, respectively.

Duty A

Research and analyze data with 7 tasks under this duty, including conducting market research to understand user needs and trends, analyzing competitor products and industry standards, creating user characters and scenarios based on research insights, collaborating with stakeholders to gather project requirements, use AI tools for trend analysis and predictive insights, conducting surveys and focus groups to gather qualitative data, and identify potential risks and opportunities through data analytics. These are the essential tasks that product designers perform in various industries. Looking into the complexity of the tasks under this duty, they utilize AI in some of the tasks to speed up the design process and predict user preferences. This aligns with previous studies where researchers considered this duty and tasks as the first phase of the product design process (Cheng, 2018). Moreover, market and user research are identified as one of the primary activities of a product designer (Hemant et al., 2017).

Duty B

The ideate concept was the second duty identified and validated by the DACUM panel. This duty involved tasks such as generating innovative product ideas and concepts, using AI-based design generation tools to accelerate concept creation, sketching initial designs and concepts, creating low-fidelity prototypes or wireframes for initial validation, developing mood boards and style guides for visual inspiration, conducting brainstorming sessions with cross-functional teams, and incorporating user feedback into iterative design concepts. These tasks allow a product designer to lay the foundation for innovation, problem-solving, and user-centered solutions. The tasks allow designers to explore ideas, evaluate possibilities, and refine concepts before committing to development. The findings congruent with the studies conducted on concept ideation where researchers opined that these days, product designers are leveraging technological trends such as generative AI, big data, and the internet of things to enhance the quality and quantity of innovative product ideas (Tauqeer & Bang, 2020; Wadinambiarachchi et al., 2024).

Duty C

Implementing the design model is the third duty, according to the DACUM panel findings. This duty incorporates tasks like creating detailed product designs using CAD software, developing high-fidelity prototypes and 3D models, specifying materials, finishes, and manufacturing processes, ensuring alignment with brand guidelines and aesthetic standards, and integrating sustainability principles into design decisions. Through these tasks, product designers transform abstract ideas into tangible forms, allowing designers to test functionality, aesthetics, and ergonomics. Physical or digital models help identify design flaws early, refine details, and improve user interaction before mass production (Saleh et al., 2019). A study conducted on model making to improve the design process supported these findings, where they highlight that physical and CAD models enhance design projects, emphasizing the importance of model making in understanding detailing, materialization, and systematic design processes (Surwade et al., 2023).

Duty D

Test and validate design appeared to be the fourth duty according to the DACUM panel. The findings deal with tasks including conducting usability testing with prototypes, gathering user feedback and refining designs based on insights, ensuring product compliance with regulatory standards, conducting quality assurance checks before production, using AI tools for automated testing and defect detection, conducting A/B testing to compare design alternatives and validating designs through virtual reality (VR) simulations. These tasks ensure a product meets functional, aesthetic, and user experience requirements before production. Testing helps identify design flaws, usability issues, and performance limitations, allowing for necessary refinement. Validation ensures the final product aligns with user needs, industry standards, and market expectations. A study on the crucial role of design validation explained that rigorous design validation enhances product functionality, reliability, and safety, leading to improved customer satisfaction and reduced costs associated with product failures, which supported this study's finding on the importance of this duty and tasks (Arain, 2023).

Duty E

According to DACUM panel findings, the fifth duty is optimizing design, comprising tasks like analyzing user behavior and performance metrics, identifying areas for design improvement, implementing design changes and updates, and utilizing AI-driven simulation tools for stress testing and optimization. These findings were supported by Meng et al., (2019)They said design optimization is essential in the product design process as it ensures that a product meets performance, cost, and sustainability goals while maximizing efficiency and functionality. It involves refining materials, structures, and manufacturing processes to enhance durability, usability, and production feasibility using AI tools like NFX Midas and Ansys (Zhu et al., 2021). Key tasks in optimization include analyzing design constraints, conducting simulations, improving ergonomics, reducing waste, and integrating innovative technologies (Sharma et al., 2022). By continuously refining and testing the design, optimization minimizes inefficiencies, enhances product quality, and ensures market competitiveness, eventually leading to a well-balanced and high-performing final product (Choi et al., 2019).

Duty F

The sixth duty in the DACUM workshop findings is design detailing and documentation. The tasks explored under this duty include preparing product documentation and user manuals, documenting design processes and decisions, and detailing manufacturing drawings. Design detailing and documentation are crucial in the product design process. Product designers provide precise specifications, ensuring accuracy, consistency, and manufacturability through design detailing. Detailing tasks include defining dimensions, materials, tolerances, and assembly instructions, which help translate design concepts into functional products. Product designers are further involved in creating detailed technical drawings, bills of materials, and manufacturing guidelines from the CAD model. A study on the investigation of the document creation process in design supported these findings by explaining that proper documentation made by product designers enhances communication between designers, engineers, and manufacturers, reduces errors, ensures regulatory compliance, streamlines production, and reuses the design information (Lin Yu-Tzu, 2021). Through maintaining thorough records, companies can improve efficiency, support future modifications, and ensure a smooth transition from design to production.

Duty G

The seventh duty from the DACUM panel findings is design presentation. The tasks associated with this duty include creating presentations for stakeholders, using AI tools, VR/AR to generate videos for presentations, and creating different views of the product to present the best outlook. Design presentation is a crucial step in the product design process. Product designers use design presentation skills to communicate ideas, concepts, and final product solutions to stakeholders, clients, and manufacturers. A study on the impact of product presentation stressed that a well-structured presentation developed by a product designer helps gain approval, gather feedback, and align all parties on design intent (Boardman & McCormick, 2019). Key tasks include creating visual renderings, 3D models, prototypes, mood boards, and presentation decks that showcase functionality, aesthetics, and usability (Choi et al., 2019). It also involves storytelling, persuasive communication, and technical explanations to ensure clarity (Glaser & Reisinger, 2022). Strong design presentations enhance decision-making, facilitate collaboration, and increase the likelihood of a successful product launch.

Duty H

Collaboration with manufacturing engineers is the eighth duty based on the DACUM findings. It includes tasks related to collaborating with engineers for product feasibility and manufacturability, collaborating with manufacturing teams for tooling and production setup, monitoring the initial production runs to ensure quality, assisting in product launch and marketing strategies, training sales and support teams on product features and benefits, and using collaborative AI tools for team coordination and project tracking. Collaboration with manufacturing engineers is essential in the product design process to ensure that designs are innovative and feasible for production. Product designers should involve manufacturing engineers early in the product design process to help optimize materials, processes, and costs while minimizing production challenges. The recent development in Industry 4.0 technologies enables and simplifies collaboration in the product design process, supporting the integration of AI competencies in product design collaboration (Gebhardt et al., 2022). Furthermore, a study on the knowledge-based collaboration model supported that collaboration in the product design process improved knowledge sharing, enhanced teamwork, and better decision-making (Benabdellah et al., 2024).

Table 3.1 DACUM chart explored product design job components

Duties	**Tasks**
A - Research and analyze data	A1 Conduct market research to understand user needs and trends A2 Analyze competitor products and industry standards A3 Create user characters and scenarios based on research insights A4 Collaborate with stakeholders to gather project requirements A5 Use AI tools for trend analysis and predictive insights A6 Conduct surveys and focus groups to gather qualitative data A7 Identify potential risks and opportunities through data analytics

B - Ideate concept	B1 Generate innovative product ideas and concepts B2 Use AI-based design generation tools to accelerate concept creation B3 Sketch initial designs and concepts B4 Create low-fidelity prototypes or wireframes for initial validation B5 Develop mood boards and style guides for visual inspiration B6 Conduct brainstorming sessions with cross-functional teams B7 Incorporate user feedback into iterative design concepts
C - Implement design model	C1 Create detailed product designs using CAD software C2 Develop high-fidelity prototypes and 3D models C3 Specify materials, finishes, and manufacturing processes C4 Ensure alignment with brand guidelines and aesthetic standards C5 Integrate sustainability principles into design decisions
D - Test and validate design	D1 Conduct usability testing with prototypes D2 Gather user feedback and refine designs based on insights D3 Ensure product compliance with regulatory standards D4 Perform quality assurance checks before production D5 Use AI tools for automated testing and defect detection D6 Conduct A/B testing to compare design alternatives D7 Validate designs through virtual reality (VR) simulations
E - Optimize design	E1 Analyze user behavior and performance metrics E2 Identify areas for design improvement E3 Implement design changes and updates E4 Utilize AI-driven simulation tools for stress testing and optimization
F - Detail and document design	F1 Prepare product documentation and user manuals F2 Document design processes and decisions F3 Detail manufacturing drawings
G - Present design	G1 Create presentations for stakeholders G2 Use AI tools, VR/AR to generate videos for presentations G3 Create different views of the product to present the best outlook
H - Collaborate with manufacturing engineers	H1 Collaborate with engineers for feasibility and manufacturability H2 Collaborate with manufacturing teams for the tooling and production setup H3 Monitor initial production runs to ensure quality H4 Assist in product launch and marketing strategies H5 Train sales and support teams on product features and benefits H6 Use collaborative AI tools for team coordination and project tracking

Ai Competencies

The expert panel identified and validated 12 AI competencies required for a product designer in the era of Industry 4.0, as presented in Table 4.1. In a period of rapid technological advancement, AI competencies have become essential for product designers to remain competitive and innovative. AI-driven tools, such as DALL·E and Midjourney, enhance efficiency, creativity, and problem-solving by generating design alternatives and predicting user preferences. As industries increasingly adopt AI for data-driven decision-making, designers must develop proficiency in AI applications in product design duties and tasks such as AI application in user and market research, concept ideation, product modeling, etc. Competencies such as AI design informatics skills, CAD modeling and simulation skills, AI-driven prototyping, and prompt engineering skills are critical for a product designer to leverage these tools effectively in this era. Without these competencies, designers risk falling behind in an industry prioritizing speed, personalization, and intelligent automation. A wider gap between the TVET programs and the industry needs may continue to evolve. Therefore, integrating AI knowledge into TVET programs in Nigeria ensures that future professionals can harness AI to improve product functionality and user experience.

Several studies have underscored the significance of integrating AI competencies into product design courses. Research by Hou et al., (2021), highlights that in this era of AI-assisted product design, students need AI competencies such as the ability to sort information with AI and the ability to apply AI tools in the product design process, as AI-assisted design systems such as DALL·E, Midjourney, and Stable diffusion can optimize creativity by analyzing vast datasets and suggesting novel design solutions that humans might overlook (Aphirakmethawong et al., 2022). Similarly, Patel et al., (2024), found that AI integration in product design accelerates prototyping and enhances human-AI collaboration, leading to more efficient innovation cycles. These studies suggest that AI is not merely a supplementary tool but a transformative force that reshapes how designers approach ideation, development, and production. As AI continues to evolve, academic institutions and industry leaders emphasize the necessity of equipping designers with AI-related skills to bridge the gap between traditional design methods and emerging technological advancements (Liu et al., 2023).

The application of AI in product design spans various domains, including generative design, user experience optimization, and predictive modeling. AI-powered software such as Autodesk's generative design tools enable designers to explore thousands of design iterations based on predefined constraints, significantly reducing development time (Buonamici et al., 2020). Additionally, AI enhances user experience research by analyzing behavioral data to tailor products to individual preferences (Sheta, 2021). Given these capabilities, it is crucial to teach students AI competencies to prepare them for industry demands. Incorporating AI competencies in the TVET product design curriculum ensures that graduates can effectively collaborate with AI tools, fostering a new generation of designers in Nigeria who can create intelligent, adaptive, and user-centric products. Thus, the identified AI competencies by the DACUM panel are beneficial in product design and imperative for sustaining innovation in the digital age (Hao et al., 2021).

Table 4.1 AI competencies for product design

S/N	**AI utilization competencies:**
1	Foundational AI Knowledge
2	AI Tools & Software Skills
3	AI design informatics skills
4	CAD modeling and simulation skills
5	AI-Driven Prototyping
6	Ethical AI Design
7	Advanced AI Applications
8	Coding & Development Knowledge
9	Staying Updated
10	Prompt engineering
11	Collaboration & Communication
12	Workflow Optimization

Product Design Skills

Product design skills are essential for creating innovative, functional, and user-centered products that meet consumer needs and market demands. According to DACUM panel findings, as shown in Table 5.1, these skills encompass a broad range of competencies, including Creative thinking and problem-solving, Proficiency in CAD, AI, and other design software, Excellent sketching abilities, Strong communication and presentation, Team collaboration and project management, Attention to detail and precision, Rapid prototyping and 3D modeling, Analytical and problem-solving skills, Effective teamwork, AI integration and data analytics proficiency, and User research methods, usability testing, empathy mapping.

Product design skills are used throughout product development, from conception to production. Designers originate and improve ideas during the conceptualization process using digital modeling tools, sketching, and brainstorming approaches. Skills like CAD modeling, Attention to detail and precision, Rapid prototyping and 3D modeling, and Analytical and problem-solving skills are needed for product designers to use in prototypes and testing to ensure that designs fulfill functional and aesthetic requirements. Professionals incorporate eco-friendly materials and energy-efficient production procedures into their workflows because of the increased focus on sustainable design. Effective teamwork, AI integration, data analytics proficiency, and User research methods, usability testing, and empathy mapping skills help product designers ensure that products are both viable and impactful by bridging the gap between concept and market-ready innovation through the application of a combination of technical, artistic, and analytical talents.

Empirical research underscores the significance of product design skills in driving business success and innovation. A study by Ali et al., (2023) highlights that product designers need skills such as creativity and the ability to navigate uncertainty, collaboration and interaction, positive attitudes and enthusiasm, and technical knowledge and proficiency, reinforcing the DACUM panel findings. Similarly, Lin and Li, (2018) emphasize the need for designers to adapt to changes by enhancing their creative abilities, embracing cross-disciplinary perspectives, and focusing on practical problem-solving. They also highlight the importance of cooperation and collaboration skills, harmonizing technology, materials, usage, modeling, and fostering sustainable learning and innovation skills, which also support the skills identified by the DACUM panel (Adelabu & Fatuyi, 2020).

Table 5.1 Product Design Skills

S/N	**Skills:**
1	Creative thinking and problem-solving
2	Proficiency in CAD, AI, and other design software
3	Excellent sketching abilities
4	Strong communication and presentation
5	Team collaboration and project management
6	Attention to detail and precision
7	Rapid prototyping and 3D modeling
8	Analytical and problem-solving skills
9	Effective teamwork
10	AI integration and data analytics proficiency
11	User research methods, usability testing, and empathy mapping

CONCLUSION

There is a growing need for TVET graduates in Nigeria to have skills that could enable them to fit into the contemporary industry trend, which requires TVET institutions to provide the necessary education for students to help them seamlessly shift to the industry 4.0 skills demand. This study uses the DACUM method to establish key product design job components to guide the TVET stakeholders in designing a curriculum linking

TVET institutions and industries. In a two-day DACUM workshop, necessary duties, tasks, AI competencies, and product design skills were identified.

Eight main duties are identified and prioritized in order of importance, and then several tasks are presented for each duty. AI competencies and product design skills needed in product design jobs are discussed and introduced. A survey was conducted to validate these identified duties and tasks for integrating AI competencies and product design skills in TVET programs in Nigeria. Then, the next step is further studying and reviewing existing TVET curricula to develop integration strategies and frameworks, and to explore the weaknesses of the existing curriculum and the strengths that integration of these AI competencies and product design skills could provide to various TVET programs. The results of this study contribute to knowledge and provide a resource for TVET institutions and TVET government regulatory bodies to develop a curriculum and industry to have documented requirements of the product designer job profile in the era of Industry 4.0.

Although the DACUM process is a reliable tool for developing occupationally relevant curricula, this study has certain limitations. All participants in the DACUM workshop were drawn from specific industry sectors furniture design and construction, mechanical or metal work, and plastic molding. Given the diversity of TVET programs, which also include fields such as leatherwork, interior design, automotive design, and agricultural equipment design, the findings are inherently biased toward the participants' areas of specialization and the northwestern region of Nigeria. To address this, similar studies should be replicated across other TVET sectors and geographic regions in Nigeria to ensure broader applicability.

Moreover, while this study focused on identifying competencies required for AI-integrated product design, merely exploring the product designer job profile is insufficient to fully support integration into TVET curricula. Future research should propose a comprehensive framework or pilot instructional module that demonstrates how these identified competencies can be effectively taught and assessed within TVET institutions. This should include pedagogical strategies, student-centered learning activities, appropriate learning environments, and resource requirements. In addition, incorporating a critical analysis of implementation challenges such as infrastructural deficits, digital literacy gaps among instructors, and institutional readiness as well as exploring policy implications, will significantly enhance the study's utility for curriculum planners, institutional leaders, and national policymakers. By merging these elements with the present findings, future iterations can provide a robust and actionable guideline for AI competency integration in TVET product design programs.

Conflict Of Interest

No potential conflict of interest.

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