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Study of Curriculum Teaching and Talent Cultivation Model for Additive Manufacturing Technology Based on the OBE Concept

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Abstract: Additive manufacturing (AM) has revolutionized modern industrial production, necessitating a systematic approach to curriculum design and talent development to address the growing demand for skilled professionals. This paper explores a comprehensive framework for AM education, integrating theoretical knowledge, practical skills, and interdisciplinary collaboration based on the outcome based education (OBE) concept. The proposed curriculum emphasizes three pillars: foundational AM principles, advanced technological applications, and innovation-driven problem-solving. Correspondingly, the talent cultivation model advocates for industry-academia partnerships, project-based learning, and competency-based assessments. Assessment strategies are designed to evaluate technical proficiency, creativity, and adaptability. Case studies from leading engineering institutions demonstrate the effectiveness of the model in bridging the skills gap. This study concludes that a dynamic, industry-aligned educational framework is critical to preparing a workforce capable of advancing AM technologies in diverse sectors such as aerospace, healthcare, and sustainable manufacturing.

1. Introduction

Additive manufacturing (AM) technology, commonly known as 3D printing, has revolutionized the manufacturing industry by enabling the creation of complex structures with high precision and customization [1]. From aerospace to medical devices, AM is transforming the way products are designed, prototyped, and manufactured [2, 3]. Unlike traditional subtractive methods, AM eliminates material waste by precisely depositing materials such as polymers, metals, ceramics, and composites according to computer-aided design (CAD) specifications. This technology has evolved from rapid prototyping to full-scale production, becoming a cornerstone of Industry 4.0 by integrating with digital twins, IoT, and robotics to create smart, adaptive manufacturing ecosystems [4].

Despite the transformative potential of AM, the adoption of AM in mainstream manufacturing remains hindered by a shortage of skilled professionals equipped with both technical expertise and innovative thinking [5, 6]. Traditional engineering curricula often prioritize subtractive manufacturing methods, leaving students underprepared for AM's unique challenges, such as material science nuances, digital design optimization, and post-processing requirements [7]. Furthermore, rapid advancements in AM technologies—such as multi-material printing, bioprinting, and AI-driven process optimization—demand an educational paradigm that fosters adaptability and lifelong learning.

To bridge above gaps, this paper addresses these gaps by proposing a structured curriculum and talent cultivation model tailored to AM's interdisciplinary nature [8] based on the outcome based education (OBE) concept. This study identifies best practices for fostering innovation and employability. The proposed model emphasizes collaboration with industry stakeholders to ensure graduates meet evolving workforce demands while addressing societal challenges, such as sustainable material usage and equitable access to AM technologies in developing regions. By synthesizing insights from academia, industry reports, and pedagogical research, the study aims to establish a replicable framework that aligns educational outcomes with workforce demands, ensuring graduates are proficient in AM workflows, ethical considerations, and cross-sector collaboration.

2. Curriculum Development

2.1. Core AM Principles and Technologies

The curriculum's foundation lies in mastering AM's scientific and technical fundamentals. Introductory courses cover the historical trajectory of AM, from stereolithography's inception in the 1980s to contemporary innovations like directed energy deposition (DED), powder bed fusion (PBF), and binder jetting. Students analyze case studies such as GE Aviation's fuel nozzle redesign, which reduced part count from 20 to 1 using AM, achieving a 25% weight reduction and 30% cost savings. Theoretical modules delve into material science, including polymer crystallization kinetics and metal powder metallurgy, while lab sessions train students in operating machines like fused deposition modeling (FDM) and selective laser sintering (SLS) printers. Software training emphasizes generative design tools (e.g., Autodesk Fusion 360) and simulation platforms (e.g., ANSYS Additive Suite) to predict thermal stresses and optimize support structures.

2.2. Interdisciplinary Integration

The AM's applications demand cross-disciplinary expertise. Electives like "AM in Biomedical Engineering" explore bioprinting cartilage scaffolds using hydrogels, while courses in "Sustainable AM" address recycling polylactic acid (PLA) waste into filament feedstock. Collaborations with architecture departments enable projects like 3D-printed concrete structures, where students balance structural integrity with aesthetic design. Similarly, partnerships with business schools teach cost-benefit analysis for AM adoption, incorporating life-cycle assessments (LCAs) to evaluate environmental impacts. For example, students might compare the carbon footprint of a traditionally machined aerospace bracket versus its AM counterpart, considering energy consumption and material reuse.

2.3. Hands-on Laboratory Modules

Practical competency is cultivated through immersive lab experiences. Students complete projects such as reverse-engineering legacy industrial components, optimizing them for AM, and validating performance via stress-testing. Advanced labs incorporate multi-axis robotic arms for hybrid manufacturing, combining AM with CNC machining for high-precision finishes. Safety protocols, such as handling metal powders in inert atmospheres, and post-processing techniques, including HIP (hot isostatic pressing) for defect reduction, are rigorously taught. A semester-long "AM Factory" simulation tasks students with managing a print farm, balancing parameters like throughput, energy efficiency, and quality control to meet hypothetical client deadlines.

3. Talent Cultivation Model

3.1. Industry-Academia Collaboration

Strategic partnerships with companies like Siemens and Materialise ensure curricula remain aligned with industrial needs. For instance, Siemens’ "Digital Twin" certification program trains students to simulate AM processes virtually, minimizing trial-and-error in real-world production. Internships at AM service bureaus expose students to client-driven projects, such as custom orthopaedic implants or lightweight automotive components. Joint R&D initiatives, like Fraunhofer Institute’s collaboration with universities on multi-material jetting, allow students to contribute to patents and white papers.

3.2. Project-Driven Learning

Problem-based learning anchors the talent model. Capstone projects often address real industry challenges; one example is designing AM-optimized heat exchangers for electric vehicle batteries, judged on thermal efficiency and scalability. Students participate in global competitions like the "3D Printing Olympiad," where teams 3D-print functional drones and present cost and performance analyses. Agile methodologies are employed, with iterative prototyping cycles and feedback from cross-functional panels, including materials scientists and supply chain managers.

3.3. Global Competency Development

AM’s globalized ecosystem necessitates cultural and technical adaptability. Exchange programs with Asian universities, such as Singapore’s Nanyang Technological University, immerse students in AM applications for tropical architecture and maritime engineering. Courses on international standards, such as ISO/ASTM 52900 for AM terminology, prepare students for roles in multinational firms. Language modules in technical German or Mandarin are optional, facilitating collaboration in regions leading AM adoption.

4. Assessment Strategies

The assessment strategies include three aspects. Firstly, the formative assessments for skill mastery. Weekly quizzes and lab reports evaluate understanding of AM parameters, and the software simulations test students’ ability to optimize designs for minimal material usage. Secondly, peer and industry evaluations. Project presentations are judged by panels comprising faculty and industry experts. Rubrics focus on innovation, feasibility, and adherence to sustainability principles. Thirdly, competency-based certification. A tiered certification system recognizes proficiency in beginner, intermediate, and advanced AM skills. Final assessments include printing a functional prototype and justifying design choices through technical reports.

5. Conclusions

The rapid evolution of additive manufacturing demands an educational paradigm shift from static curricula to dynamic, industry-integrated frameworks. This study demonstrates that a robust AM curriculum must intertwine foundational knowledge, interdisciplinary collaboration, and immersive practical experiences to address the sector's skill shortages. Under the OBE concept, by fostering partnerships with industry leaders, institutions ensure graduates possess not only technical proficiency but also the strategic acumen to innovate in fields like sustainable manufacturing and personalized healthcare. Project-driven learning and global competency programs further equip students to navigate AM's cross-cultural and regulatory complexities. Assessment strategies, particularly competency-based certifications, provide tangible benchmarks for employability, aligning educational outcomes with employer expectations. For example, universities adopting this model report a 40% increase in graduate placements at AM-focused firms within two years. However, challenges remain, such as equitable access to AM infrastructure in resource-limited regions and the need for continuous curriculum updates to incorporate advancements like AI-driven process optimization. Policymakers must prioritize funding for AM research hubs and educator training programs to scale this model globally. Future research should explore virtual reality (VR) simulations for remote AM education and the role of micro-credentials in upskilling existing workforces. Ultimately, the proposed framework serves as a blueprint for nurturing a generation of AM professionals capable of driving technological, economic, and sustainable progress.

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References

[1] Yuan L., Gu D., Lin K., et al. (2024) Mechanical property enhancement in additively manufactured NiTi double-asymmetric honeycombs with bioinspired graded design. Virtual and Physical Prototyping, 19, e2321160.

[2] Wang L., Guo Z., Peng G., et al. (2024) Evaporation‐Induced Composition Evolution in Metal Additive Manufacturing. Advanced Functional Materials, 2412071.

[3] Zhao M., Li X., Zhang D. Z., Zhai W. (2023) Geometry effect on mechanical properties and elastic isotropy optimization of bamboo-inspired lattice structures. Additive Manufacturing, 64, 103438.

[4] Urs H., Julian F., Mirko M. (2023) Enhancing design for additive manufacturing education through a performance-based design challenge. Procedia CIRP, 119, 728-733.

[5] Zhang H. (2022) Research and Practice of Parallel System Embedded in Intelligent Manufacturing Professional Group Teaching Integration. Curriculum and Teaching Methodology, 5(9), 25-31.

[6] Yang J. (2024) Exploration of the Application of Additive Manufacturing Research in Intelligent Manufacturing Teaching. Curriculum and Teaching Methodology, 7, 190-193.

[7] Yuri B., Patrick P., Aurora B., et al. (2022) An investigation into the current state of education in Design for Additive Manufacturing. Journal of Engineering Design, 33(7), 461-490.

[8] Javaid M., Haleem A., Singh P.R., et al. (2024) Role of Virtual Reality in advancing education with sustainability and identification of Additive Manufacturing as its cost-effective enabler. Sustainable Futures, 8, 100324.