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Integrating 3D Technology in Sculpture Courses: Challenges, Strategies, and Recommendations

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Abstract:- The integration of 3D technology into sculpture courses presented both opportunities and challenges for students and educators alike. This research investigated the current landscape, challenges, strategies, and recommendations associated with incorporating 3D technology in sculptural courses. Through a comprehensive review and analysis, key challenges emerged, including the complexity of technology, inadequate educational resources, varying levels of instructor expertise, and practical issues such as equipment maintenance and material properties. These challenges highlighted the need for targeted interventions to enhance educational effectiveness and accessibility. Strategies proposed included curriculum enhancements to integrate 3D technology, professional development programs for educators, improvements in technology interfaces, and collaborations between industry and academia. These strategies aimed to address identified challenges and optimize learning experiences in sculpture courses. Recommendations emphasized the development of centralized educational platforms, increased funding for 3D research, advocacy for regulatory standards, and the establishment of peer learning networks. These initiatives sought to foster a supportive environment conducive to innovation and creativity in sculptural arts education. By addressing these technological complexities, enhancing educational resources, improving instructor proficiency, and overcoming practical barriers, this study advocated for a comprehensive approach to integrating 3D technology effectively into sculpture courses, ultimately empowering students and educators to use their full potential in artistic expression and professional practice.

Keywords:- *3d Technology, Sculpture Courses, Educational Technology.*

I. INTRODUCTION

In recent years, the field of art education has been revolutionized by advancements in technology, particularly in the domain of three-dimensional (3D) technology. One particular area where these advancements have shown great potential is in sculpture courses. Traditionally, sculpture education has relied on traditional techniques such as hand-carving and modeling with clay. However, with the use of 3D technology in it introduces new possibilities and challenges traditional practices. It is a revolutionary force in this era of rapid technological advancement, impacting the creation, innovation, and delivery of many industries. Its influence is seen deeply in academia and business, from conception to real manifestation [23]. At Any age student may explore their creative side and translate their ideas into useful things through learning. Students may build practical projects—like 3D-printed statues—and use these projects to learn more rapidly and effectively. With the use of these devices, students may receive tactile, visual, and auditory feedback to aid in their understanding of various styles and designs [1]. 3D technology has transformed the classroom experience by offering students hands-on experience in various areas to make products from digital designs to actual products encouraging students' creativity, problem-solving abilities, and involvement [23]. The advantages of employing 3D in education are numerous, and as technology advances, it will undoubtedly become a popular tool [1].

With the use of 3D models, educators may effectively explain difficult learning concepts. Teachers might transform difficult subjects into tangible objects that students can handle and examine. They may assist children in developing critical skills by exposing them to real-world problems through the use of 3D technology [12]. For example, students studying mathematics can make scale models to help solve difficult mathematical equations, think creatively, and explore novel learning possibilities. Science teachers might utilize three-dimensional depictions of atoms, molecules, and other scientific constituents. The use of 3D technology ensures that students retain the topics covered in class thereby increasing their confidence in their ability to apply learning to real products [14]. Thus, 3D technology offers a good tool to turn soft copies of images into actual objects.

This study examined the impact of integrating 3D technology in sculpture courses. The objective is to identify the knowledge level in terms of concepts, skills, processes, benefits, and challenges associated with the use of 3D technology in sculpting education and its significant differences based on age, year level, and gender. By conducting a comprehensive analysis, this sought to provide valuable inputs to develop a manual.

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II. IMPORTANCE OF THE STUDY

The findings of this study can have significant implications for various stakeholders in the university. It will contribute to the existing body of knowledge on integrating 3D technology in sculpture. By exploring the benefits and challenges associated with the use of it, this study provided valuable insights for educators, students, and professionals in the field of sculpture. This may encourage them to adopt this innovative method, offering students a more comprehensive and engaging learning experience. Art students, in turn, may be inspired to experiment with 3D technology as a novel approach to their sculpting projects, allowing them to explore a wide range of materials and techniques. Art teachers, who provide sculpture-making lessons, can introduce this new medium to their students, enabling them to create numerous 3D artworks using various materials. Artists may discover a time- and cost-efficient method to produce outstanding pieces of art, offering them the freedom to experiment with diverse materials such as plastic, metal, and wood. The study also presented opportunities for researchers to further explore their interests, collaborate with art teachers and students, and use the current study as a foundation for future research. This will influence future curriculum development and inform decisions related to the implementation of 3D technology in sculpture courses.

A. Statement of the Problem

- How did the respondents assess their knowledge level in the integration of 3D technology in their sculpture courses in terms of;
  - concepts
  - skills
  - processes?

- Is there a significant difference in the respondent's concept and skills level when grouped according to
  - age
  - year level
  - gender?

- What potential challenges or limitations are associated with the adoption of 3D technology in sculpture education?
- Based on the findings, what strategies and recommendations may be proposed?

B. Research Hypothesis

HO: There is no statistically significant evidence that the mean knowledge levels in terms of concept and skills differ between males and females, among the three age groups, or between grade 2 and grade 3 students.
H1: There is statistically significant evidence that the mean knowledge levels in terms of concept and skills, differ between males and females, among the three age groups, or between grade 2 and grade 3 students.

C. Scope and Limitations of the Study

The study investigated the respondents' knowledge and skills in the use of 3D technology in sculpture-making of art students where students answered a validated questionnaire to assess their level of knowledge and skills including the problems and challenges in the use of 3D technology in the sculpture-making and production. The survey of this study was conducted within three weeks and limited the respondents to the art students and art teachers at Wuhan University of Technology.

D. Conceptual Frameworks

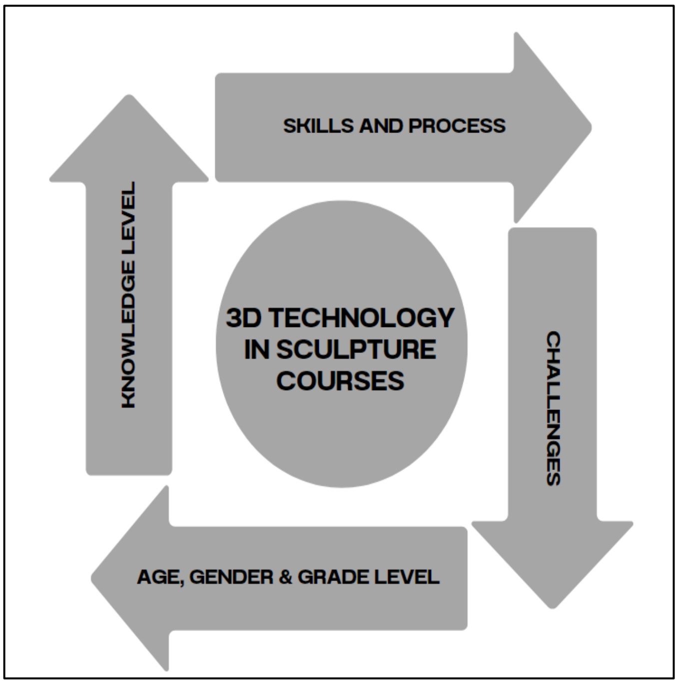

Fig 1 Conceptual Frameworks

III. RESEARCH DESIGN AND METHODOLOGY

To achieve the research objective, a mixed-methods approach was employed. The research included both quantitative and qualitative analysis. Quantitative research methods involved surveying both students and teachers to gather data on their experiences and perceptions of integrating 3D technology in sculpture courses. This provided numerical data that were statistically analyzed to examine trends and patterns. Qualitative research methods involved in-depth interviews with instructors and students, as well as observation of sculpture courses incorporating 3D technology. This provided insights into the benefits, challenges, and overall impact of 3D technology during the interview process.

The study was conducted at Wuhan University of Technology in China, the data represents responses from 150 individuals who are predominantly young adults between the ages of 21 and 23, with the majority being either 22 or 23 years old. In terms of gender, the respondents are evenly split, with 75 females and 75 males. Regarding their educational level, the respondents are almost equally distributed between grade levels 2 and 3, with 72 individuals

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in grade 2 and 78 in grade 3. The respondent pool consists of a balanced mix of young adults from both genders, providing a diverse perspective on the topics covered in the survey. The researcher used an online survey to gather data, which was validated by Filipino and Chinese experts. The questionnaire consisted of four parts: respondent profile, level of knowledge, skills, problems, and challenges encountered in using 3D technology. The data was analyzed using statistical tools such as the weighted mean, t-test, and analysis of variance (ANOVA) to identify the status of knowledge and skills and to analyze the differences between groups. The problems and challenges were thematically analyzed using the MAXQDA tool.

A. Related Literature and Studies

The goal of this study was to assess the current knowledge and skills in using 3D technology for sculpture-making among Chinese art instructors and students. The study explores various theories and advancements regarding the significance of 3D in sculpting education, drawing from multiple studies and books to formulate its aims. Despite the potential of 3D technology, some view it as "manufactured" or "cheating" rather than "real art." Integrating digital techniques into traditional studios can be challenging, although some artists claim it has extended their careers [15]. Teachers can use 3D technology to encourage students to experiment. Today's artists use 3D printing, scanning, milling, and sculpture to create unique works that were previously impossible [15].

These technologies provided new tools and speed up the creative process, giving artists more time for their work. The accessibility and affordability of 3D printers have made them valuable educational tools [1]. Researchers are interested in how students who have never used a 3D application learn by simply using it. Even when classes are designed to fail, the introduction of new technology can motivate students to engage without becoming discouraged [15]. More research is needed on specialized teaching strategies because learning 3D software fosters the development of original concepts [23]. Software proficiency is crucial for 3D application, with programs ranging from simple primary school applications to complex tools for specialists. However, some studies raised concern about 3D technology's impact on the financial prospects and symbolic value of copyrighted works, despite the legal challenges in enforcing copyright over reproductions [8]. With all of these points and issues, 3D technology presented challenges and opportunities, in its integration into sculpture courses. Further investigation is needed whether it holds significant potential or hampers the innovation and creativity of students.

Table 1.1 Knowledge Level Of Art Students In Terms Of Concepts In The Use Of 3D Technology

Indicators	Mean	S.D.	VI
1. 3D technology can be integrated into sculpture-making and production	2.30	0.90	Slightly Knowledgeable
2. 3D technology is an important aid in sculpture printing	2.30	0.90	Slightly Knowledgeable
3. 3D technology has advantages over the traditional sculpture-making	2.40	0.94	Slightly Knowledgeable
4. 3D technology is a process that uses computer-aided design, or CAD, to create objects layer by layer.	2.39	1.00	Slightly Knowledgeable
5. Computer-aided design (CAD) is used for 3D modeling software to create or reproduce geometric forms.	2.36	0.98	Slightly Knowledgeable
6. 3D technology is an additive process whereby layers of material are built up to create a 3D part.	2.48	0.96	Slightly Knowledgeable
7. 3D technology can make abstract concepts more concrete, and enable students to create their models, prototypes, or artifacts.	2.54	0.98	Slightly Knowledgeable
8. The accuracy of the 3D technology can be tested by running a test with a calibration cube.	2.31	1.03	Slightly Knowledgeable
9. 3D projects, can foster creative thinking and problem-solving skills, as well as technology skills	2.44	0.94	Slightly Knowledgeable
10. Filament quality, bed leveling, and print speed are factors that affect 3D printing quality	2.36	1.03	Slightly Knowledgeable
Weighted Mean	2.48	0.96	Slightly Knowledgeable

As gleaned from Table 1.1, the weighted mean score of 2.48, which is also categorized as " Slightly Knowledgeable," suggests that the overall knowledge level of art students regarding the concepts and applications of 3D technology is relatively low. The standard deviations were all close to 1, suggesting variability in the responses across knowledge levels. This indicated a need for more educational efforts or training programs to enhance the understanding and utilization of 3D printing technology among art students, particularly in the field of sculpture-making and production.

The indicators cover various aspects of 3D printing technology, such as its integration into sculpture-making (x=2.30), its advantages over traditional methods (x=2.30), the use of computer-aided design (CAD) in 3D modeling and printing (x=2.36), the additive process of 3D printing (x=2.48), its ability to make abstract concepts more concrete (x=2.54), the testing and calibration of 3D printed parts (x=2.31), and the potential of 3D printing to foster creative thinking and problem-solving skills (x=2.44).

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3D printing technology is rapidly expanding in various industries, enabling mass customization and production of open-source designs [19]. The recent awareness of it as applied in different fields is causing the vast development of the global economy. It made mass production possible in China and caused big changes in the production and manufacturing industry. Combining 3D with other technologies promoted the third industrial revolution in many countries including China [23].

Table 1.2 Knowledge Level of Art Students in Terms of Skills in the Use of 3D Printing Technology

Indicators	Mean	VI	V.I.
1. Design supports and slices	2.39	0.85	Slightly Knowledgeable
2. Import data into the printer	2.43	0.88	Slightly Knowledgeable
3. Handle machine cleaning and maintenance equipment	2.26	0.83	Slightly Knowledgeable
4. Perform different methods and technology to post-process parts	2.27	0.82	Slightly Knowledgeable
5. Apply approaches to powder removal	2.17	0.87	Slightly Knowledgeable
6. Support the removal process	2.07	0.80	Slightly Knowledgeable
7. Perform the cut and grind process of the product	1.96	0.82	Slightly Knowledgeable
8. The Filling process of the product	1.88	0.76	Slightly Knowledgeable
9. Paint and coat the pre-finished product	1.93	0.75	Slightly Knowledgeable
10. Polish and stitch together printed models	1.90	0.78	Slightly Knowledgeable
Weighted Mean	2.12	0.81	Slightly Knowledgeable

Table 1.2 presents ten indicators related to various skills required for the effective utilization of 3D technology, ranging from designing supports and slicing models to post-processing and finishing printed parts. The weighted mean score of 2.12, which is also categorized as low, suggests that the overall skill level of art students in using 3D technology is relatively low. This could indicate a need for more practical training and hands-on experience to enhance the skills of art students in various aspects of 3D application, from design and preparation to post-processing and finishing.

For each indicator, the mean score falls between 1.88 and 2.43, which is categorized as low level of skill. These indicators cover essential skills such as importing data into the printer (x=2.43), handling machine cleaning and maintenance (X=2.26), performing different post-processing methods, applying approaches to powder removal, supporting the removal process, cutting and grinding printed parts (x=1.96), filling processes, painting, and coating, as well as polishing and stitching together printed models (x=1.90) Developing these skills is crucial for art students to effectively leverage the capabilities of 3D printing technology in their creative endeavors, particularly in the field of sculpture-making and production. Addressing this skill gap through targeted training programs or curriculum modifications could potentially enhance the overall understanding and proficiency of art students in utilizing 3D printing technology.

Table 1.3 Knowledge Level of Art Students in Terms of Processes in the Use of 3D Printing Technology

Indicators	Mean	VI	
1. Interpret and follow reference material to create clean, detailed, and accurate models	1.31	0.85	No knowledge at all
2. Perform post-processing procedures	1.26	0.79	No knowledge at all
3. Select a specific parameter editor to understand the values and the implications for data preparation.	1.33	0.88	No knowledge at all
4. Design prepare or fix a 3D model for the sculpture	1.27	0.85	No knowledge at all
5. Select the right quality part parameters for each case	1.16	0.77	No knowledge at all
6. Performs computational modeling	1.22	0.80	No knowledge at all
7. Follows the data preparation process	1.26	0.88	No knowledge at all
8. Post-processing procedures as well as machine cleaning and maintenance.	1.28	0.85	No knowledge at all
9. Handle the processing software, the set-up, and job start	1.35	0.89	No knowledge at all
10. Handle and operate the 3D machine and its peripherals.	1.35	0.89	No knowledge at all
Weighted Mean	1.27	0.84	No knowledge at all

Table 1.3 presents the results of a survey assessing the level of knowledge among individuals in various indicators related to 3D modeling and processing. The survey results indicate that the overall level of knowledge among the individuals surveyed is relatively low, with a weighted mean of 1.27, classified as "No knowledge at all." This suggests

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that there is a significant lack of knowledge in some areas while indicating a moderate to high level of knowledge in others. This could indicate a need for more comprehensive training or educational programs to enhance the understanding and practical skills of art students in various aspects of the 3D technology process, from model preparation and data handling to machine operation and post-processing techniques.

The mean scores for each indicator range from 2.24 to 2.31, these indicators cover essential processes such as interpreting reference materials to create accurate models (x=1.31), performing post-processing procedures (x=1.26), selecting appropriate parameter editors for data preparation (x=1.33), designing or fixing 3D models for sculpture (x=1.27), selecting the right quality part parameters (x=1.16), performing computational modeling (x=1.22), following data preparation processes (x=1.26), handling post-processing and machine maintenance (x=1.28), operating the 3D printing software and job setup (x=1.35), and operating the 3D printing machine and its peripherals (x=1.35).

Fine arts classes in special schools enhance children's emotional knowledge, mental and volitional qualities, and improve hand-motor skills, while also promoting cognitive activity and cognitive development [5]. Mastering these processes is crucial for art students to effectively utilize the technology in their creative endeavors, particularly in the field of sculpture-making and production. Also, 3D technology, including environments, images, holograms, and prints, positively impacts student learning in health care education, enhancing skills, knowledge, perceptions, and emotions [24]. Learning in and through arts significantly expands the scope of knowledge-creating learning in secondary education, preparing students for an innovation-driven knowledge society [18]. Addressing this knowledge gap through targeted training programs or curriculum modifications could potentially enhance the overall proficiency of art students in leveraging the full potential of 3D printing technology in their artistic pursuits.

TABLE 2 DIFFERENCES IN THE KNOWLEDGE OF THE USE OF 3D TECHNOLOGY IN TERMS OF CONCEPTS ACCORDING TO AGE, YEAR LEVEL, AND SEX

Indicators	Gender		Age		Grade Level	
	F	p	F	p	F	p
1. 3D technology can be integrated into sculpture-making and production	0.035	0.852	0.235	0.79	2.119	0.147
2. 3D technology is an important aid in sculpture printing	0.028	0.568	0.094	0.910	1.835	0.177
3. 3D technology has advantages over the traditional sculpture-making	0.081	0.776	0.147	0.863	0.722	0.397
4. 3D technology is a process that uses computer-aided design, or CAD, to create objects layer by layer.	0.074	0.785	0.108	0.898	1.045	0.308
5. Computer-aided design (CAD) is used for 3D modeling software to create or reproduce geometric forms.	0.077	0.781	0.011	0.989	0.889	0.347
6. 3D technology is an additive process whereby layers of material are built up to create a 3D part.	0.075	0.784	0.130	0.878	1.304	0.255
7. 3D technology can make abstract concepts more concrete, and enable students to create their models, prototypes, or artifacts.	0.224	0.624	0.155	0.857	2.161	0.143
8. The accuracy of the 3D technology can be tested by running a test with a calibration cube.	0.226	0.635	0.027	0.973	0.687	0.408
9. 3D projects, can foster creative thinking and problem-solving skills, as well as technology skills	0.224	0.629	0.055	0.947	1.058	0.305
10. Filament quality, bed leveling, and print speed are factors that affect 3D printing quality	0.077	0.781	0.023	0.977	0.889	0.347

Table 2 presents the data on differences in the knowledge level in terms of concepts on the use of 3d printing technology in sculpture according to age, year level, and sex. The null hypothesis is that there is no difference in the mean knowledge levels between males and females, as well as between age groups of 21, 22, and 23 years old, and between grade 2 and grade 3 students, for each indicator. The alternative hypothesis is that there is a difference among at least two of the groups. The F-statistic represents the ratio of the variation between the groups to the variation within each group, with a larger F-statistic indicating a greater difference between the groups. The p-value is the probability of observing an F-statistic as extreme as the one calculated, typically, a p-value less than 0.05 is considered statistically significant, meaning we can accept the null hypothesis.

Looking at the results, none of the indicators have a p-value less than 0.05. The smallest p-values are 0.624 for the comparison between males and females for indicator 7 ("Makes abstract concepts more concrete"), 0.791 for the comparison between age groups for indicator 1 ("Integrate concepts in sculpture making/production"), and 0.143 for the comparison between grade 2 and grade 3 students for indicator 7. Therefore, based on the ANOVA results, we fail

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to reject the null hypothesis for all indicators. There is no statistically significant evidence that the mean knowledge levels differ between males and females, among the three age groups, or between grade 2 and grade 3 students in this dataset.

The F-statistics are also relatively small for all indicators, suggesting that the variation in knowledge levels within each group is much larger than the variation between the groups. While there may be some minor differences in the mean knowledge levels across the groups, the ANOVA suggests that these differences are not large enough to be considered statistically significant. The ANOVA analysis suggests that the group, male/female, age, or grade level, does not have a significant impact on the knowledge levels related to 3D printing and sculpture concepts in this particular dataset. These findings have the same result in mathematics assessment where females perform equally to males on mathematics assessments, with a small gender difference in verbal skills. However, in terms of art skills, a moderate advantage for males in 3D mental rotation was found [11]. 3D animation combined with sound material effectively enhances IT learning for adult learners aged 20-30, making it a valuable tool for enhancing learning methods [12]. This confirms that age affects the level of theory understanding of 3D printing and it emphasizes the readiness of students for the complex cognitive process and emotional experience that they will undergo with this new technology.

Table 3 Differences in the Knowledge of the Use of 3D Technology in terms of Skills According to Age, Year Level, and Sex

Indicators	Gender		Age		Grade Level	
	F	p	F	p	F	p
1. Design supports and slices	0.02	0.892	0.63	0.533	16.36	0.00
2. Import data into the printer	0.08	0.775	0.87	0.420	15.63	0.00
3. Handle machine cleaning and maintenance equipment	0.14	0.713	1.92	0.149	16.93	0.00
4. Perform different methods and technology to post-process parts	0.13	0.716	1.63	0.198	16.94	0.00
5. Apply approaches to powder removal	0.17	0.680	2.44	0.089	22.07	0.00
6. Support the removal process	0.04	0.834	3.57	0.030	23.56	0.00
7. Perform the cut and grind process of the product	0.01	0.940	5.22	0.006	32.96	0.00
8. Filling process of product	0.00	0.993	6.78	0.001	43.30	0.00
9. Paint and coat the pre-finished product	0.00	0.978	7.14	0.009	43.53	0.00
10. Polish and stitch together printed models	0.00	0.973	5.99	0.003	38.28	0.00

The data analysis of the impact of gender, age, and grade level on various 3D printing tasks reveals several key insights. Gender has no significant effect on any of the tasks, as indicated by high P-values across all categories. Age, however, shows a significant impact on more advanced tasks such as performing the cut and grind process (F=5.22, P=0.006), filling process (F=6.78, P=0.001), painting and coating (F=7.14, P=0.009), and polishing and stitching together models (F=5.99, P=0.003). The grade level has a highly significant impact on all tasks, with P-values of 0.00 in each category, and high F-statistics ranging from 16.36 to 43.53, suggesting that higher education or experience levels significantly improve task performance. This data indicates that while gender does not affect proficiency, age-specific training may be beneficial, especially for more complex tasks, and that advancing one's grade level or education plays a crucial role in enhancing 3D printing skills.

There is no significant effect of gender on the performance of any 3D printing tasks. This is indicated by the high P-values (all above 0.05), suggesting that gender does not influence proficiency in these tasks. However, age significantly affects performance on several more advanced 3D printing tasks. Specifically, significant effects are observed in tasks such as performing the cut and grind process (F=5.22, P=0.006), the filling process (F=6.78, P=0.001), painting and coating the pre-finished product (F=7.14, P=0.009), and polishing and stitching together printed models (F=5.99, P=0.003). This indicates that older individuals may perform better on these complex tasks compared to younger individuals. It is noteworthy that Grade level consistently shows a highly significant impact on performance across all 3D printing tasks. The P-values for grade level are all 0.00, with F-statistics ranging from 16.36 to 43.53. This suggests that as grade level (likely indicative of experience or education) increases, proficiency in these tasks significantly improves.

This data indicates that while gender does not affect proficiency, age-specific training may be beneficial, especially for more complex tasks, and that advancing one's grade level or education plays a crucial role in enhancing 3D printing skills. These data implied that the lack of gender significance suggests gender-neutral capabilities in performing 3D printing tasks. The significant impact of age on certain advanced tasks suggests the need for age-specific training or support, particularly for more complex processes, and the strong influence of grade level highlights the importance of advanced training and education in improving performance in 3D printing tasks.

These trainings may be of good use because 3D technology has revolutionized biomedical applications, offering customized implants, prostheses, organ printing, and tissue engineering, with promising future opportunities [5]. The gained skills can transform teaching and learning by fostering creativity, innovation, and problem-solving as core practices, aligning with the latest learning sciences research [10].

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Table 4 Challenges Encountered by the Student and Teachers in the Use of 3D Technology in Sculpture Education

Theme	Instances	Summary
Complexity and Usability	31	The complexity of 3D printing technology and its processes is a major hurdle. Many find the machinery and software difficult to use and understand. There is also frustration with the steep learning curve and the technical challenges involved in setting parameters, modeling, and post-processing.
Practical Challenges	27	Practical challenges include issues with equipment availability, maintenance, and the technical aspects of printing and post-processing. Respondents highlight problems such as print head blockages, material shrinkage, and the need for continuous adaptation to new technologies. Seasonal changes and material properties also complicate the printing process.
Learning Resources	23	There is a significant need for accessible and comprehensive educational resources on 3D printing. Many respondents struggle with the complexity of the technology and express a desire for more structured and effective learning materials, including tutorials, textbooks, and systematic courses.
Cost	22	Many respondents find the cost of 3D printing materials and equipment prohibitively expensive. This financial burden limits their ability to practice and utilize 3D printing technology extensively. The high costs also impact the ability to maintain and upgrade equipment, which poses an ongoing challenge.
Instructor and Curriculum Issues	16	There are concerns about the quality of teaching and curriculum related to 3D printing. Some respondents note that their instructors are not well-versed in the technology, and there is a lack of comprehensive teaching plans and resources. This results in a fragmented learning experience.
Miscellaneous	6	Other challenges include the rapid pace of technology updates, compatibility issues, and the diverse needs of students which make standardization difficult. The sense of isolation due to a lack of universal education resources is also mentioned.

Table 4 reveals the challenges the user faces in 3D technology arranged in critical themes that impact its widespread adoption and application. Cost emerges as a significant concern (instances = 22), with equipment costs, material expenses, and ongoing maintenance highlighted as key issues. Stakeholders cite the high initial investment and continuous operational expenses as prohibitive factors, constraining widespread adoption. As one respondent noted, "The cost of 3D printing is prohibitive for regular use." Learning resources constitute another pivotal theme, (instances = 23), encompassing tutorials, textbooks, courses, and online materials. Despite the abundance of resources, challenges such as a lack of structured educational content and accessibility issues persist. This deficiency limits the ability of users to acquire essential skills and knowledge. As highlighted by feedback, "There is a significant lack of accessible educational resources." Complexity and usability stand out as critical challenges within the 3D printing landscape (instances = 31). Issues such as machine usability, software complexity, and technical hurdles contribute to a steep learning curve for beginners. Adjusting parameter settings and overcoming modeling difficulties further complicate the user experience. Concerns voiced include perceptions that "The technology is too complex for beginners."

Moreover, instructor and curriculum-related issues, also feature prominently (instances = 16), reflecting gaps in instructor knowledge and fragmented teaching methods. This theme underscores the importance of educator expertise and the need for cohesive, well-structured curricula to effectively impart 3D printing skills. Stakeholders lamented that "Instructors are not well-versed in 3D Technology." Practical challenges (instances = 27) encompass a range of issues including equipment maintenance, technical glitches, and environmental factors. Machine breakdowns and the variability of material properties pose significant operational hurdles. Seasonal changes further exacerbate these challenges, affecting production consistency and reliability. Participants emphasized that "Maintenance of the equipment is a significant issue."

Lastly, miscellaneous factors (instances = 6) such as rapid technology updates, compatibility concerns, and the lack of standardization add another layer of complexity. The dynamic nature of 3D printing technologies necessitates constant adaptation, which can overwhelm both users and industry stakeholders alike. Stakeholders cautioned that "The pace of technology updates is overwhelming." 3D printing holds immense promise, and addressing these thematic challenges is crucial for its sustainable integration and advancement across various sectors.

Educators and students alike face significant challenges in integrating 3D into educational settings, particularly 3D application have advanced over the last 20 years, but challenges in capture, modeling, image formation, and analysis remain, highlighting the need for future research and applications [10]. These dynamics demand teachers to develop curricula from scratch, leading to frustrations with the lack of standardized educational frameworks. The broader implications of dimensional technologies on cultural works emphasize concerns over restrictions on availability and duplication within the public domain [23].

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In addressing educational challenges, artificial intelligence (AI)-assisted teaching methods have shown promise in enhancing academic performance and satisfaction.3D game-based learning systems in software engineering curriculum improves learning achievement and motivation, leading to higher satisfaction and confidence levels compared to traditional face-to-face teaching. [21] Moreover, the teaching of contemporary art in K-12 settings presents additional complexities, including the need for supplementary lessons beyond traditional mediums, addressing controversial topics, and increased preparation time for developing original art units [22]. These insights highlight ongoing efforts and innovative approaches in navigating the evolving landscape of art education amidst technological advancements and educational reforms.

IV. FINDINGS

- There is some awareness of 3D printing technology among art students, the findings suggest a need for targeted educational interventions to deepen their knowledge and proficiency across various dimensions of this emerging technology, thereby empowering them to leverage its potential more effectively in artistic endeavors.
- Addressing skill gaps through targeted training programs or curriculum enhancements could significantly enhance the overall proficiency and integration of 3D printing within artistic education, thereby better preparing students for future creative endeavors.
- The low overall level of knowledge among respondents needs to be attended with a focus on educational efforts to bridge knowledge gaps and enhance practical skills related to 3D modeling and processing, thereby empowering individuals to harness the full potential of 3D printing in their creative endeavors.
- There is no difference in the knowledge levels between males and females, as well as between age groups of 21, 22, and 23 years old, and between grade 2 and grade 3 students in terms of concepts.
- The significant impact of age on certain advanced tasks suggests the need for age-specific training or support, particularly for more complex processes, and the strong influence of grade level highlights the importance of advanced training and education in improving performance in 3D printing tasks.
- The grade level has a highly significant impact on all tasks, suggesting that higher education or experience levels significantly improve task performance in 3D technology.
- The challenges in 3D education, including a critical need for accessible learning resources, frustration with technology complexity and usability, concerns over instructor expertise and curriculum quality, practical issues like equipment maintenance and adaptation to new technologies, and broader challenges with rapid updates, compatibility issues, and diverse student needs, necessitating comprehensive solutions to enhance educational effectiveness and accessibility.

V. CONCLUSION

There were no discernible differences in knowledge levels between genders, age groups, or specific grade levels in basic concepts. However, higher grade levels significantly enhance task performance in 3D technology, indicating the value of advanced training initiatives. The influence of age and educational level on performance in advanced tasks suggests the importance of tailored training and support mechanisms.

Moreover, the findings presented several critical aspects of 3D education that warrant attention and action. There is a recognized awareness of 3D technology among art students, yet the study reveals significant gaps in knowledge and proficiency. Targeted educational interventions are essential to deepen understanding and skill across various dimensions of this technology, empowering students to effectively utilize it in artistic pursuits. Addressing these skill gaps through focused training programs or curriculum enhancements holds promise in enhancing overall proficiency and integration of 3D printing within sculpture courses. This proactive approach not only prepares students better for future creative endeavors but also aligns educational outcomes with industry demands and technological advancements.

The study also highlights the overarching need for accessible learning resources, concerns about technology complexity and usability, and challenges regarding instructor expertise and curriculum quality. Practical issues such as equipment maintenance and adaptation to new technologies further underscore the complexity of integrating 3D printing into educational settings. Addressing these multifaceted challenges requires comprehensive solutions aimed at enhancing educational effectiveness, improving accessibility to learning resources, and fostering a supportive environment for both educators and learners. This approach will not only bridge existing knowledge gaps but also empower individuals to harness the full potential of 3D printing technology in their creative and professional endeavors.

RECOMMENDATIONS

- Create centralized platforms with curated content, tutorials, and courses accessible to students and educators of all levels. Ensure these resources cover both foundational concepts and advanced techniques in 3D technology.
- Establish targeted training programs that focus on practical skills such as 3D modeling, machine operation, and post-processing techniques. These programs should be tailored to address the specific needs and skill levels of art students and educators.
- Update and standardize curricula to integrate 3D technology effectively across educational institutions. Ensure that curricula reflect current industry practices and advancements to better prepare students for future creative and professional pursuits.
- Offer ongoing professional development opportunities for educators to enhance their knowledge and proficiency in 3D printing technology. Provide access to training workshops, seminars, and certifications to ensure they remain well-versed in the latest developments.

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- Allocate resources to research and develop intuitive software interfaces and user-friendly controls for 3D technology. This will lower the learning curve and improve usability for both students and educators.
- Foster partnerships and collaborations between industry experts and educational institutions to co-create relevant curriculum materials and provide real-world insights. This collaboration ensures that educational programs align with industry needs and technological advancements.
- Implement predictive maintenance technologies to reduce equipment downtime and ensure reliability. Develop strategies to mitigate practical challenges such as material handling, environmental factors, and equipment maintenance.
- Encourage government and private sector investment in research and development aimed at lowering equipment costs and advancing 3D materials and technologies.
- Establish platforms for students and educators to share best practices, collaborate on projects, and exchange ideas related to 3D technology. Encourage a culture of peer learning and continuous improvement within educational communities.
- Engage with regulatory bodies to establish guidelines and standards that promote innovation while ensuring the safety, quality, and ethical use of 3D technology.

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