DEVELOPMENT OF THE KNOWLEDGE AND SKILLS IN THE APPLICATION OF ADDITIVE MANUFACTURING AMONG THE GRADUATE STUDENTS OF MINDANAO STATE UNIVERSITY-ILIGAN INSTITUTE OF TECHNOLOGY: A MIXED-METHOD DESIGN RESEARCH

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ABSTRACT. *It is important to understand that there's nothing permanent in this world and to keep up with the competition, every individual must continue to equip themselves with new learnings to cater to the needs of society required in the 21st century. According to the study conducted by the World Bank and the National Economic and Development Authority (NEDA), the Philippines is still lagging when it comes to technology adoption, and a call to improve its digital infrastructure must be made to help the country recover from the effects of the COVID 19 pandemic. The study aimed to develop the knowledge and skills in the application of additive manufacturing among the 30 Master of Arts in Education majors in Technical, Vocational, and Livelihood Education (MAED-TVLE) students of MSU-Iligan Institute of Technology. The study employs a mixed-method research design through standardized paper and pen exams, skills assessment using a validated rubric, and a semi-structured online interview to support statistical results. It was found that the participants significantly improved their knowledge and skills after the training by using the Additive Manufacturing Training Module for Technology Students, which guided them in creating their desired 3D model. The researcher concluded that the training being implemented was successful, and the training module helped supplement the participants' learnings. Therefore, it is highly recommended the incorporation of additive manufacturing subject into the Philippine education curriculum as this will give both teachers and learners a glimpse of what Industry 4.0 is.*

Key Words: Additive manufacturing, experimental mixed-method design research, Additive Manufacturing Training Module for Technology Students

1. INTRODUCTION

Many companies are already revolutionizing the way they manufacture their products. From the traditional handmade crafts to the computer-numerically controlled router that can create wooden designs in just a matter of minutes, it seems that what people saw in science fiction films is coming into reality. These companies are now incorporating new technologies such as Artificial Intelligence (AI), the Internet of Things (IoT), and cloud computing into their manufacturing and throughout their operations which gave way to the birth of the fourth industrial revolution, simply called Industry 4.0. It continues what the third industrial revolution started by incorporating smart machines into the whole production ecosystem.

In the Industry 4.0 environment, interconnected computers, smart materials, and intelligent machines communicate with one another, interact with the environment, and eventually make decisions with minimal human involvement. The resulting "smart factory" will bring customers and suppliers closer together, as production orders will be sent by the customer directly to the machine, and the production data will be transferred to the distribution partner in real-time [1]. One of the key pieces of evidence that Industry 4.0 is already happening is the presence of additive manufacturing. Additive manufacturing is a set of production technologies that allow for obtaining a final product through the generation and subsequent addition of layers of material. It describes it as "those processes that aggregate materials to create objects starting from their three-dimensional mathematical models, usually by overlapping layers and proceeding in the opposite way to what happens in subtractive processes [2].

When it comes to technological advances, the Philippines lags behind its neighboring countries as it failed to associate science, technology, and innovation as core parts of the development plan. Based on the survey conducted by the World Economic Forum, the Philippines ranked 64th out of 141 countries in the Global Competitive Index and ranked 88th in ICT adoption. The studies show that the Philippines needs to accelerate when it comes to welcoming technological changes and needs to keep up with the pace to stay competitive.

Based on the Philippine News Agency, in the southern part of the country, particularly Northern Mindanao, the misconceptions that additive manufacturing is an expensive technology are hindering its use, and the local 3D printing sector has to fully mature to realize its full potential. The researcher of the study discovered no existing related literature concerning the incorporation of additive manufacturing in Philippine school curriculums. Thus, it validates the claims that the country's technology is still in its infancy.

2. METHODOLOGY

This study measured the knowledge and skills of selected thirty (30) MAED-TVLE students of MSU-Iligan Institute of Technology before and after the implementation of additive manufacturing training through the use of the Additive Manufacturing Competency-Based Training Module for Technology Students. The researcher used the sequential explanatory mixed-method research design involving only a one-group pretest-posttest design. This approach is when a researcher is interested in gathering quantitative and qualitative data results. Thus, the qualitative is used in

translating and explaining the outcomes of the quantitative data analysis [3].

In this study, the researcher administered one group with a pretest and posttest before and after introducing the participants to additive manufacturing training. After the posttest, the participants were asked to do a return demonstration on how to create a 3D model using different software applications. An interview was followed after collecting the quantitative data from the participants. The research design flow is presented in Figure 1.

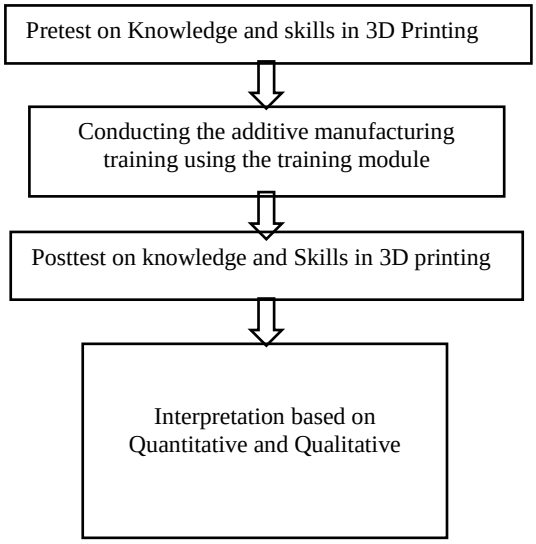

Figure 1. **The Flow of the study**

The researcher utilized the purposive sampling technique for choosing the research respondents. Is known as selective or subjective sampling, a method in which the researchers depend on their judgment in choosing the population members to participate in the survey [4]. This sampling technique also requires the researcher to have existing knowledge about the purpose of their study so they can appropriately select and approach qualified respondents using online survey platforms. The respondents were chosen based on the following criteria: (a) must be an official student under the MAED-TVLE program, (b) must be currently employed or teaching in a private or public institution, and (c) must be willing to undergo training and participate in the research as a respondent.

For the qualitative part, the researcher purposely selected five (5) respondents willing to participate in the interview. Several articles, book chapters, and books advocate for guidance and recommend a minimum of 5 participants for conducting a qualitative research study [5].

Since this study used the sequential explanatory mixed-method research design, in quantitative data collection, the researcher used a teacher-made standardized test that assesses participants' knowledge which was performed online. Certain rules were implemented such as a time limit on each item and limited attempts to ensure the reliability of the test. Also, a validated rubric was developed and verified by the experts of the academe to attest to the validity of the tools. The rubric was used to measure the skills of the 30 MAED-TVLE students during their return demonstration in 3D modeling. The activity was performed face-to-face to carry out intervention during the return demonstration. For the qualitative data, the research instrument was the researcher who conducted interviews through video communication. The duration of the whole training went for four weeks.

The researcher developed the training module used during the training following the TESDA Competency-Based Learning Material format. The instructional material was also guided using the Revised Bloom's Taxonomy in Instructional Design which helps establish pedagogical interchange between the teacher and the students and is the best source of writing objectives [6].

The researcher used descriptive statistical techniques like frequency, standard deviation, and mean in the data analysis. In addition, an inferential statistic like the T-test was used to determine the significant difference between the pretest and posttest scores. Being one of the most important steps in conducting statistical data analysis, descriptive statistics, as the name suggests, is a type of data analysis that helps constructively describe data points [7]. Also, a t-test is a statistical test used to compare the means of two groups [8]. In this study, the t-test is the right inferential statistics to test the respondents' significant difference between the pretest and posttest.

Furthermore, the researcher used a thematic analysis to determine the emerging themes of the respondents on how the training helped the MAED-TVLE students achieve their three-dimensional model. To have good qualitative research, the study itself needs to be able to translate and be consistent with the data that are being collected. In light of this, thematic analysis is capable of recognizing and distinguishing, e.g., elements or factors that impact issues made by the respondents [9]. Table 1 shows how the scoring was made in the additive manufacturing training skills demonstration.

Table 1. ***Scoring the Skills in Additive Manufacturing***

Scale	Range	Response
5	4.21- 5.00	Very Good
4	3.41- 4.20	Good
3	2.61- 3.40	Fair
2	1.81- 2.60	Poor
1	1.0-1.80	Very Poor

3. RESULTS AND DISCUSSION

Table 2 shows a significant difference in the mean scores between the pretest and posttest in terms of Knowledge (Rapid Prototyping and Software programs used in 3D modeling).

One sample T-test was performed to test the significant difference in the mean scores between the pretest and posttest for the knowledge test of the participants of this study. The results from the pre-test *(M = 6.80, SD = 2.31)* and post-test *(M = 10.50, SD = 1.36)* revealed that the training on Knowledge (Rapid Prototyping and Software programs used in 3D modeling) *t(29) = 42.34, is significantly difference p<.001)* as indicated in Table 2. This means that the respondents dramatically improve their knowledge level after the implementation of the training in 3D printing.

Table 2. The significant difference between the pretest and posttest for Knowledge Test in Rapid Prototyping and Software programs used in 3D modeling (n= 30)

	Mean	SD	t-value	df	p-value	Remarks
Pretest	6.80	2.31	16.12	29	p<0.001	Supported
Post-test	10.50	1.36	42.34			

Table 3 shows a significant difference between the pretest and posttest regarding their skills (Creation and manipulation of 3D models and model slicing and printing).

One sample T-test was performed to test the significant difference in the mean scores between the pretest and posttest for the skills demonstration of the respondents of this study. The results from the overall pretest (M = 1.22, SD = 0.10) and overall posttest (M =4.75, SD = 0.45) revealed that the training in the Creation and Manipulation of 3D models (skills set 1) and 3D Model Slicing and Printing (skills set 2) significantly difference at p<.001) as indicated in Table 3. This means that the respondents improve remarkably during their demonstration level after the implementation of the training in both 2 sets of skills in 3D modeling

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Table 3. The significant difference between the pretest and posttest for Skills Demonstration on Creation and Manipulation of 3D Models and 3D Model Slicing and Printing (n= 30)

	Criteria	*pretest*			*posttest*			*p value*
		Mean	*SD*	*Description*	*Mean*	*SD*	*Description*	
Skills 1	Opening the software tool	2.47	0.91	Poor	4.97	0.18	Very Good	<0.01
	Setting Up Preferences	1.00	0.00	Very Poor	4.83	0.38	Very Good	<0.01
	Touring the User Interface	1.27	0.45	Poor	4.87	0.43	Very Good	<0.01
	Checking the Navigation	1.00	0.00	Very Poor	4.77	0.43	Very Good	<0.01
	Importing a File from the Data Panel	1.00	0.00	Very Poor	4.67	0.48	Very Good	<0.01
	Creating a 2D Sketch	1.00	0.00	Very Poor	4.87	0.45	Very Good	<0.01
	Finishing the Sketch	1.00	0.00	Very Poor	4.53	0.51	Very Good	<0.01
	Applying Extrusion	1.00	0.00	Very Poor	4.83	0.46	Very Good	<0.01
	Saving the Model as Mesh	1.00	0.00	Very Poor	4.87	0.35	Very Good	<0.01
	Selecting the Model for Slicing	1.00	0.00	Very Poor	4.73	0.45	Very Good	<0.01
	Exporting as STL file	1.00	0.00	Very Poor	4.83	0.38	Very Good	<0.01
Skills 2	Opening the Software Tool	1.43	0.50	Very Poor	4.87	0.35	Very Good	<0.01
	Importing the STL file	1.00	0.00	Very Poor	4.87	0.35	Very Good	<0.01
	Scaling the 3D Model	1.00	0.00	Very Poor	4.80	0.49	Very Good	<0.01
	Rotating the Model	1.00	0.00	Very Poor	4.63	0.56	Very Good	<0.01
	Laying the Model Flat	1.00	0.00	Very Poor	4.63	0.56	Very Good	<0.01

Selecting the Correct Material	1.00	0.00	Very Poor	4.33	0.61	Very Good	<0.01
Slicing the Model	1.00	0.00	Very Poor	4.57	0.63	Very Good	<0.01
Saving the File for 3D Printing	1.00	0.00	Very Poor	4.77	0.50	Very Good	<0.01
Overall	*1.11*	*0.10*	*Very Poor*	*4.75*	*0.45*	*Very Good*	*<0.01*

Table 4 shows the thematic analysis of how the training helped the MAED-TVLE students in attaining their desired 3D model. The data collected were analyzed through content analysis techniques, and the Acquisition of New Knowledge and Skills emerged as the main theme. The table presents the codes, categories, and themes corresponding to participants' narratives during the interview.

Table 4. Emerged Themes on How the Training Helped the Respondents

Codes	Categories	Emerging Theme
First-time encounter	Exposure to new learnings	Acquisition of new knowledge and skills
New skills unlocked		
Additional knowledge	Application of learning	
Informative		
Producing one's correct output		
Similar to the previous training	Experience with similar training	

The theme that merged was the acquisition of new knowledge and skills. The emerged theme has three categories – exposure to new learnings, application of learning, and experience with similar training. During the interview, the participants shared their learning experiences during the training and how it gave them additional knowledge and skills.

Most of these participants expressed their firsthand experience with the software applications. Participant 1 said, *"The applications you introduced were something new to us that I don't have any idea about. That was my first time using all of those applications, especially the Ultimaker Cura and I haven't even touched a 3D printer yet. Never tried to print a 3D model all by myself though I have an idea of how to use it."* In addition, learning is the transfer of skills from the teacher to the learner, which is very important at the end of the training to let the participants demonstrate what they have learned. Participant 3 shared her enthusiasm as she mentioned, *"Sir it was my first time and it was quite amusing because I was able to create my own 3D model and it was a big help, especially for educational purposes."* Although the additive manufacturing training was something new to 30 MAED-TVLE students, some of the participants also shared their learning experiences and how it was quite similar to their previous training. Participant 2 narrated, *"Although, it was familiar because I had it during my school years and when it was introduced during the training, it was more about being informed rather than being helped. It did not directly help only but it added more."*

Whether education is formal or informal, every person needs to learn continuously. This will help the person develop new learnings that may contribute to society. According to Ambrose et al. (2010), learning is a change in behavior as a result of experience, which can lead to improved performance in an individual. Generally speaking, learning is a process of gaining new knowledge, skills, values, attitudes, and preferences that are unique to humans and other living organisms. Furthermore, a traditional classroom involves a teacher who delivers knowledge to the students and where the activities, including their time, place, and learning pace, are continuous. Ash and Clayton (2009) stated that applied learning is maximized when it is active, engaged, and collaborative.

4. CONCLUSION

Based on the results presented, the study revealed that the 30 MAED-TVLE students exhibited mastery of the subject matter. There was a huge difference in scores on their paper and pen tests, and at the same time, they performed excellently during their return demonstration. A similar study on the use of e-learning modules for medical students also proved to be effective. The knowledge and self-efficacy of the students in interpreting medical interviews were enhanced by using such a learning tool [10].

The results during the interview unfolded how the training helped the 30 MAED-TVLE students in attaining their desired 3D models. Most participants expressed how it gave them new learnings and how these will benefit them as professionals. Although some of them had experienced similar training before, still, the participants conveyed how the training gave them additional knowledge, especially on 3D modeling.

5. RECOMMENDATION

The survey results provided empirical data about the improvements in knowledge and skills of the 30 MAED-TVLE students after the implementation of the training and how the training helped craft their 3D models with the guidance of the training module. As a result of the study's discoveries and conclusions, the researcher formulated the following recommendations:

1. Government agencies concerning education (DepEd, CHED, and TESDA) must keep up with the rest of the world in terms of updating and upgrading the school's curriculum since the world is already in the phase of Industry 4.0, and the different industries are learning towards artificial intelligence. The increasing globalization, technological advancement, and improvements in research into teaching and learning methodologies are at least three factors that demand educational change [11].
2. Face-to-face classes are still better than virtual ones since they physically enrich learning through teacher and student interactions. However, the threat of unknown diseases that will turn into pandemics is still imminent with no further studies and cures, and thus, a blended learning method is still preferable to keep the safety of both learners and teachers. Education among learners will certainly continue with the introduction of training or learning modules as supplements. Based on the study entitled, *The Significance of Blended Learning in Education System*, learners are highly likely to perform better than students who attend face-to-face classes. This is because students have the opportunity to ask their queries in the classrooms and, at the same time, can take online classes whenever and wherever they are [12].
3. Training and development that will equip an individual to become future-proof must be required of every teaching personnel. School administrators must keep encouraging teachers to pursue professional development to become more effective and guarantee the quality of education they share with the learners. Acquiring professional development is essential for teachers in the 21st century. In addition, it gives them the skills and tools to keep them updated with the needs of the students and allows them to plan for changing trends in education [13].

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