



## **The Use of 3d Printing on Design Thinking in The Design Process: A Literature Review**

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### **Abstract.**

The purpose of this research is to find new way to make prototype in the design process. Technological advances in additive manufacturing technology have been growing, one of which in rapid prototype, making prototypes with the use of technology is three-dimensional (3D) printing, which works by melting thermoplastic material in the making of a model or prototype. The materials used are Polylactic Acid (PLA) and Acrylonitrile Butadiene Styrene (ABS), which are molded by melting by heating the nozzle according to the melting point and flowing in layers to form an object or objects. Design thinking is a method with a solution-based approach to solving a problem, with an iterative process to understand users, challenge an assumption, and redefine the problem to identify strategies and alternative solutions to a problem, especially in the design process. Design thinking has five steps in the process, empathize, define, ideate, prototype, and test. This literature review aims to see the influence of the prototype process on the design thinking method using 3D printing in the design process. The method used in this paper is to use descriptive qualitative research methods by analyzing the existing literature. Therefore, it can be concluded that using 3D printing in the design thinking method can be a new way of making prototypes in the design process.

**Keywords:** *3D Printing, Design thinking, Prototype*

## **INTRODUCTION**

Technology development has grown so high along with the development of the era (Marpaung, 2018). This advanced technology is in line with the growth of modern human civilization (Amri & Sumbodo, 2018). Today's technology helps people in doing their activities in the industrial sector. The industrial sector has entered Industry 4.0, where its massive growth development, especially in the manufacture, design, and innovation of a product become very important because of the tight competition and innovation that the producer made to get the people's market. In the Industry Revolution 4.0, the industries also increase automatization, such as machine-to-machine communication, human-to-machine communication, Artificial Intelligence (AI), and continuous technology development.

In order to keep the industry stable in the sales market in developing a product, industries need a high-precision and fast-production tool to make the production process more accessible, like the tool to make a prototype called a rapid prototype (Amri & Sumbodo, 2018). Before rapid prototypes existed, industries used conventional technology or manual work by a craftsman (Sutisna & Tjong, 2021). With the transformation of work systems in prototyping from conventional to machinery work, industries want to keep prototyping fast and precise. Not all industries make changes using rapid prototypes because, in some cases, industries still need a craftsman touch in the process.

The implementation of rapid prototype technology was started since many industries used CNC machines (Computer Numerical Control) in their production process. CNC machines have rapidly developed since they can easily produce complex and precise objects in large quantities. (Amri & Sumbodo, 2018). CNC Machine works by measuring the length coordinates of a 2- or 3-Dimension object that is interpreted into a G-Code command with the help of computers. The command generates a motor so that the motor will move based on the object's coordinates. The CNC machine's basic mechanism has produced many machines such as CNC routers, lathes, plasma clutter, and 3D Print. CNC machine is an easy-to-operate machine that can be applied in industries. However, it is hard to be implemented in a small industry because of its high price and maintenance. Therefore, with the technological advancement nowadays, there is a way to develop a cheap, fast, and precise 3D Printer technology to make a prototype or cast using a CNC system (Amri & Sumbodo, 2018).

3D Printer is a desktop computer fabrication tool or additive manufacturer used to create prototypes that create a physical object from 3D design. The technology that is commonly used in 3D Printing is Selective Laser Sintering (SLS) and Fused Deposition Modelling (FDM) (Gupta & Sharma,

2014). The use of a 3D printer was triggered because it can help people in the process of prototyping. In general, the process of prototyping needs a significant amount of time. This process happens because the process of making a prototype is going on several steps, from creating a design to the finishing process. Hence, the conventional way of prototyping needs a lot of workers and time to process the production of the prototype. Besides the technological advancement needed in the industrial area, 3D printers are also crucial for educational purposes. The 3D printer is an innovation of technology in the education area. 3D printers can help the learning process directly (Szulżyk-Cieplak et al., 2014).

Design thinking is an instrument used in problem-solving, problem design, and problem forming (Syahrul, 2019). It is solving a problem and forming and designing a problem. In the process, design thinking is a human-centered approach. Every design thinking process is come and directed by humans (Syahrul, 2019). Design thinking revolves around a deep interest in developing understanding from people, which becomes the objective of product designing or service. This thing helps people observe and develop empathy with the target user. Design thinking also helps us in the process of questioning, problems questioning, assumption questioning, and relation questioning. Design thinking is used in almost every scientific field, even in a country. This effort is to create a work of creation that is appropriate for humans. Developed countries used the design thinking method to dig potency and thinking in facing problems and challenges in their countries. For example, Denmark supports cross-ministries innovative organizations that combine design thinking with social science approach to create a better solution for the community (Kimbell, 2011).

In the education sector, especially in interior design, product, or graphic design, the design thinking method is often used to find the solution to an existing problem, particularly in finding the appropriate solution for the case study. In design thinking, there are five steps to be done: empathize, define, ideate, prototype, and test. Every step has a different interest, but it supports each other. One of the design learning components is teaching how industrial practice is done, so there is a need to make a learning environment that duplicates professional practice where students learn the required habit when entering the work studio (Matthee & Turpin, 2019). Moreover, the design process is one of the skills that are important to be learned.

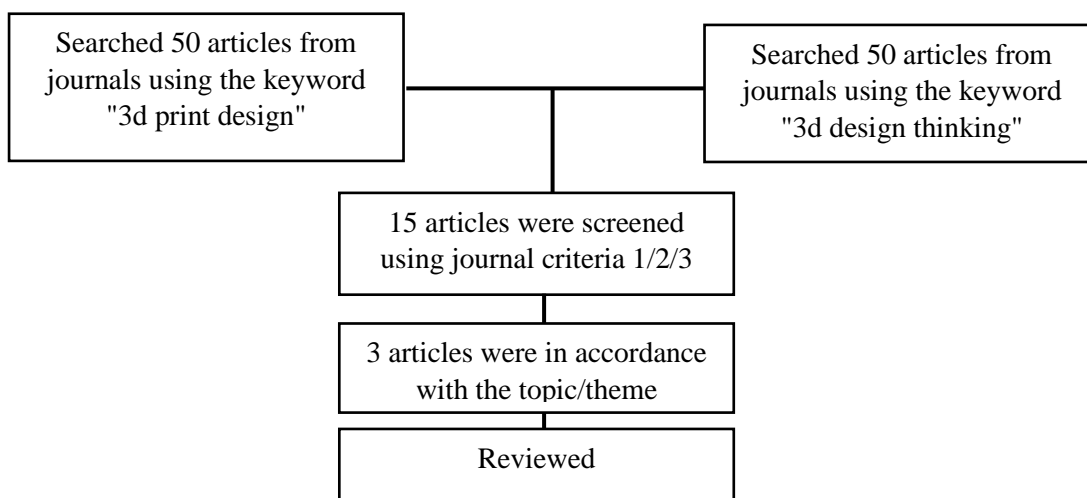
The prototype step in design thinking is one of the essential things in this step, and the final product will be tested on the target market. Market test using prototype is intended to find out whether the design or problems aimed for is appropriate or not. In the design world, the step before prototyping

is the *mock-up step*. *Mock-up* is a model created with a different scale and material than the exact product. *Mock-up* is often used for model study and for the first presentation to the customer. Usually, prototyping takes more than one-time creation. Sometimes, the prototype is not good enough for the consumer, so the process can be done several times until it comes to the final target.

With the presence of 3D printing, also called rapid prototype technology, the process of creating innovation in prototyping will be faster and more precise compared to the conventional way. There will be a transformation in the production process of prototyping, as the process of prototype reproduction using 3D printer will be faster when there is an error, and there is a need to revise the previous prototype. Even though this technology is starting to take place in the industries, it still cannot be appropriately used in the small-scale handicraft industry. The 3D printer may not be used to create the prototype, but it can be a tool to do production. Thus, could using the 3D printer in design thinking be a new way to prototype work in the design process? The purpose of this research is to find new way to make prototype in the design process.

## RESEARCH METHODOLOGY

This paper's method is a *literature review* that analyzes relevant literature on 3D Printing design thinking in the design process. The author used a qualitative approach to conduct the literature review. The author employed a literature review technique, with the stage including the search for theories and literature references relevant to the topic of the problem that the researcher investigates. A *literature review* is a study conducted to analyze selected literature reviews from various sources to reach a conclusion and develop a new idea (Sulung, 2020). The literature review scheme is depicted as a diagram in Figure 1.



**Figure 1.** Literature Review Scheme

This study's topic is related to 3D print design thinking. The researcher reviewed various references from reputable national and international journals to conduct a literature review. The literature was gathered in the form of national journals via research searches using topic keywords from 2018 to 2022. However, after screening with the criteria for the Accredited Journal of Sinta 1, 2, and 3, only three articles met the researcher's criteria. The literature review scheme is depicted as a diagram in Figure 1. In conducting a literature review, it adopts five stages, as discussed by Cahyono et al. (2019). The following stages are involved in conducting this research: (1) finding relevant literature, (2) evaluating literature review sources, (3) identifying themes and gaps between theory and conditions in the field, (4) making an outline structure, and (5) compiling the results of a literature review and drawing conclusions. Furthermore, two articles from international journals were identified in addition to strengthening the study and analysis results.

## **RESULTS AND DISCUSSION**

3D Printer is one of the latest innovation breakthroughs in the world of technology in accordance with the industrial era 4.0. More (2013) defined a 3D Printer as a desktop computer fabrication tool or additive manufacturing used for prototyping and creating real objects from 3D designs. Selective Laser Sintering (SLS) and Fused Deposition Modeling (FDM) are two technologies commonly used in 3D printers (Gupta & Sharma, 2014). 3D printing, also known as additive manufacturing, is a method of creating three-dimensional solid objects (Saxena & Kamran, 2016). 3D printing technology can be used to print objects quickly, even during the prototype design stage; hence it is famously known as "rapid prototype work on prototypes." In future developments, 3D printing technology will be used not only to make prototypes but also to make functional objects (Medellin -Castillo & Zaragoza-Siqueiros, 2019).

In the 3D printing technology process, a thermoplastic filament material is extruded through tiny nozzles into layers that stack on top of each other to form objects. The material is heated until it becomes a liquid and then pushed through small nozzles by the printer (ál & Ddi, 2020). The 3D model data will be processed during the printing process using an interface application software called software slicer to convert the stl or obj data into data that can be read by a 3D printer in the G-Code format. There are several slicer applications commonly used in 3D printing, such as TinkerCAD, Cura, Sculptris, Sketchup, Meshmixer, Ideamaker, 3D slash, Freecad, Simplify, etc. The more complete the settings in the slicer application, the higher the accuracy of the product, but the shorter the settings in the slicer application, the shorter the time for making the product. The use of slicer software, such as Slic3r, Cura, and Simplify3D, affects the accuracy of the dimensions of the printed product and the consumption of filament material (Šljivić et al., 2021).

Based on the results of design, analysis, and data processing, several things can be concluded as follows:

- a. The use of different slicers will affect the printed product's dimensional accuracy and surface roughness, presumably because the resulting algorithm differs, resulting in differences in the execution of printing orders on the 3D Printing machine. However, the input data and parameter settings for the 3D CAD (Computer-Aided Design) model are the same.
- b. Not all slicers can adjust the support if the print object has a tilt angle of more than 45 degrees. "Simplify" is a slicer software that can manage the support. The support setup can complete the
- c. printing process more quickly, and the user can position the support according to the required object. The main reason is that if the slicer software cannot set the support, the support generated will appear randomly, even in objects that should not require it.
- d. Products that do not require support have better dimensional accuracy and surface roughness than products that require support, even though they use the same slicer software (Cahyati & Aziz, 2021).

With the advancement of 3D printer technology, its application is no longer limited to industry; it is also being used in education. This technology may be the most recent educational innovation and may also aid in the learning process (Szulyk-Cieplak et al., 2014). Models or prototypes are required in design and architecture education and will be very useful if this technology is implemented in their learning.

The value of the basic principles contained in design thinking, such as understanding the basic principles of design thinking, must be understood thoroughly. The first principle is action-oriented, with design thinking resulting in a learning-by-doing approach. The second principle is becoming accustomed to change, in which design thinking proposes a new way of approaching a problem. The third principle is human-centric, which means that design thinking uses various observational activities and listening-based research techniques to systematically study each person's needs, next steps, and achievements. The fourth principle is linked to long-term objectives. The fifth principle is a dynamic and constructive process, where design thinking is an iterative process that requires definition, redefinition, presentation, re-presentation, assessment, and visualization. According to this principle, working on prototyping to produce tangible and distinguishable results is an essential component of design thinking. The sixth principle is to prioritize empathy, which places the user (customer or consumer) at the center of everything. The seventh principle, design thinking, aids in risk reduction by considering factors such as technology, market, competitors, and supply chain. The

eighth principle is creating meaning. This one is the most challenging part of the design process. In addition, the communication tools used in design thinking (models, charts, sketches, and stories) assist in framing and expressing the information required to form and socialize meaning. The ninth principle is to push creative endeavors to a higher level. Meanwhile, competitive logic is the tenth principle. Through innovation, the business strategy can transform it into a desirable product and a long-term competitive advantage (Syahrul, 2019).

*Design thinking* is an essential component of any product or artifact. From a symbolic and conceptual object, all human-made aspects of an artifact involve design thinking (Anderson & Krathwohl, 2001). *Design thinking* encompasses all types of cognitive activity, such as remembering, understanding, applying, analyzing, evaluating, and creating. The last three types of activity are higher-order cognitions required in design (Lewis & Smith, 1993). *Design thinking* necessitates a combination of lower and higher-level cognitive activities. *Design thinking* is broadly defined as activities that focus on changing natural or existing resources, such as human objects, in response to emerging human needs or desires (Brown, 2009). In this case, design thinking does not ignore the relevant cognitive and nature of human experience.

The design process is one method of solving creative problems through steps or activities that lead from the initial concept to realization or the final stage (Koberg et al., 2003). The design process involves thinking about or planning the steps necessary to create a work using one's knowledge, experience, and abilities. This process helps the designer understand the process and stages involved in creating a design, even though the design process generally follows the same steps. However, at some point, there will be pretty specific differences, depending on the type of design work done. Engaging and easy-to-understand learning media can increase motivation to study and deepen design science (Noviadji & Hendrawan, 2021).

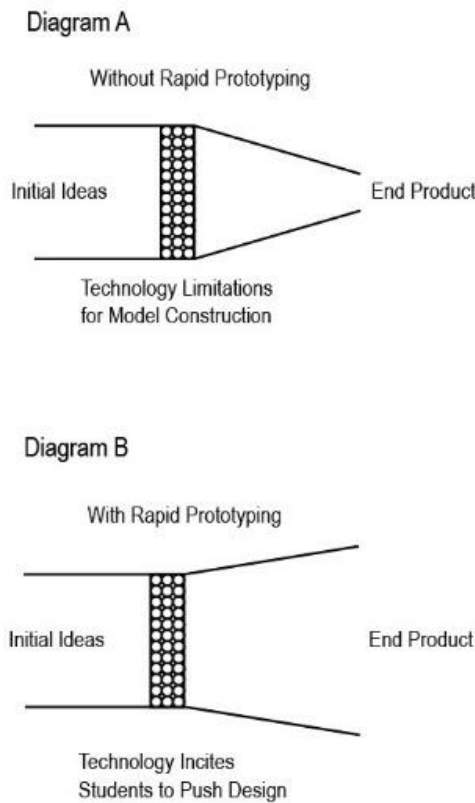
Every designer's journey through the design process is unique because every designer must be able to find the best way from within himself. On the other hand, teachers must help stimulate and introduce ways or early stages of how the process is carried out during the learning process. Models and prototypes are fundamental design tools that have been used for centuries (Wang et al., 2007). Prototypes and models serve various functions, including providing a demonstration form of the final project and providing feedback for revisions and improvements during the design process. As a result, they have been a part of the design education curriculum for over a century (Matthee & Turpin, 2019). Designs, models, and prototypes are frequently created using materials and techniques such as

wood, paper, foam, and clay. Sources such as the Technological Literacy Standards (ITEA, 2002), the National Academy of Engineering (NAE, 2002), and many leading engineering educators regard prototyping as a fundamental aspect of design (Oaks, 2003). A study is conducted before it becomes a final product to ensure that people will accept a product we produce by creating a prototype (Muliyawan, 2017).

Rapid prototyping, prototyping, and 3D printing can revolutionize or improve design education, which impacts the design process, quality of results, and products of design activities. When educators use 3D printing, it can impact the curriculum; it is also essential to identify and measure the impact of this process. Educators who study 3D printing and rapid prototyping typically concentrate on how technology affects their curriculum by identifying what teachers can do with technology or what students can do with it. Examples of identifying what teachers can do with 3D printing in the curriculum include printing physical-scale models of mechanical parts, human anatomy, science models, food, etc. (Kurman & Lipson, 2013). Similarly, several articles highlight what students can do with technology, such as projects they can create (Breen et al., 2003).

Greenhalgh (2016) discovered that students who use 3D printing outperform students who use traditional or handmade techniques on average. When students first begin designing, their minds are wide open, and they come up with very clever design concepts; however, as they begin to build conventional models and see how they will be planned, they begin to regress to straight-line design (Greenhalgh, 2016). On the other hand, students who use 3D printing technology for design planning are becoming more open, not just straightforward. However, the vision is becoming more open and may evolve into a complex design. Figure 1 depicts the distinction between the design process and 3D printing.





**Figure 2.** Different Printing Process with 3D Printer

Source: (Greenhalgh, 2016)

According to the study's findings, 3D printing may impact students' experiences with design-based learning, and students may have different experiences with design-based learning processes. Compared to traditional modeling techniques, this study shows that 3D printing technology significantly improves students' models or prototypes, particularly their ability to replicate the scale, display and craft details consistently and accurately, and overall design quality. When combined with observations from the world of education, researchers, and students, this advancement can lead to changes in learning strategies during the design process due to 3D printing technology (Duffy & Jonassen, 2013).

According to Lenior (2016), the impact of 3D printing, which is beginning to be integrated into the learning curriculum, is more significant. Students begin understanding and applying the new design process by thinking, drawing, and printing. This approach differs from the previous instruction provided by the teacher. Researchers and teachers observed that students were hesitant to revise designs and recreate the model, with less than 5% of students choosing to reprint their designs when

given the opportunity. According to the same study, students consider how a design will be printed rather than produced. They must consider the design when creating models using conventional or traditional techniques. This approach resulted in some designs that could not be produced using the usual practice. Although this study did not focus on an industry's manufacturing capabilities, designs created by students using 3D printing may impact designs when students change professions or for students studying engineering or manufacturing.

3D printing allows students to experiment with more unusual forms, which manufacturers may not be able to do if they are to be manufactured. It is suggested that design students and teachers be prepared to develop a curriculum that can handle manufacturing capabilities and a curriculum that uses traditional model construction and 3D printing (Lenoir, 2006).

Variables such as fixation, creativity, process strategy, and alternative generation all impact design quality. The ability to synthesize knowledge from multiple sources is essential to problem-solving in design thinking (Dorst & Cross, 2001). As a result, design thinking is multi-/interdisciplinary. Drawings or sketches are frequently used in problem-solving, but models, simulations, and prototypes are also created and used. This tool can be used to reduce cognitive load by representing thinking results. Besides, they serve as a foundation for knowledge accumulation and provide alternative pathways for experiential learning. Thus, they can contribute to discovering new knowledge or ways of thinking (Brown, 2009). Many attempts have been made to distinguish design thinking as a type of thinking, given its ability to generate new ideas while attempting to elevate the status of design. However, much speculation has been lost in understanding the design process and design thinking.

Some researchers believe that design thinking is ideal for dealing with ambiguous problems (Buchanan, 1995). Unclear problems cannot be fully solved because they are not fully understood. Uncertain problems are difficult to explain or define and can change over time. As a result, designers must first become involved in the process of setting or framing the problem. The range of possible solutions is determined by how the problem is framed or formulated. As the problem-solving process unfolds, problems and related solutions co-evolve symbiotically with new task goals, constraints, and insights.

## CONCLUSIONS

In the design process, where design thinking is applied, the use of 3D printing becomes a new technique in the process of making a prototype. Although it does not rule out traditional prototyping methods, 3D printing technology can save time, speed, and precision for both manufacturing industries and designers. This technology can also help to actualize innovations because 3D printing can create even the most difficult or complex objects.

With today's advanced technology, 3D printing may be one of the new ways to create a prototype. Together with the five steps in design thinking, one of which is prototyping, it is expected to pioneer a new approach to the process, particularly in creating physical prototypes.

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