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Evaluation of Key Success Factors in the Visual Optimization of the 3D Forming of Soil-Shaping Ability

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Abstract: Improving the quality of the manufacturing process is an important goal of professional technicians. This study systematically explored the key success factors in the product-forming ability and visual optimization of 3D forming in the clay-shaping process through actual manufacturing and implementation. The purpose of this study was to identify the forming technology and technical indicators that can successfully achieve a high degree of completeness and maturity in the manufacturing process, increasing the shaping performance of the end products and enabling the evaluation of optimization. In this study, we evaluated soil shaping, material use, the manufacturing process, and product forming. The key success factors were studied and analyzed via expert interviews. The research and analysis were summarized into 4 dimensions with 48 sub-dimensions. These included: (1) soil material, with 12 sub-dimensions; (2) the design concept, with 12 sub-dimensions; (3) the prototype process, comprising 12 sub-dimensions; and (4) kiln firing, comprising 12 sub-facets. A research team composed of 13 scholars and experts conducted three surveys on the evaluation dimensions of the Delphi technique. They analyzed the mean (M), mode (Mo), and standard deviation (SD) of various dimension options. They used the Kolmogorov–Smirnov one-sample test research and analysis to analyze the appropriateness and consistency of the survey results. The results of this study showed that 15 sub-dimensions met the appropriateness and consistency conditions, based on which 15 key factors were established. The results of this study provide reference indicators for the manufacturing process, forming process, and forming technology optimization quality for follow-up research.

Keywords: manufacturing process; soil shaping; forming ability; 3D forming; optimized design; Delphi technique

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Citation: Shih, F.-C.; Tsai, C.-J.; Chang, S.-H. Evaluation of Key Success Factors in the Visual Optimization of the 3D Forming of Soil-Shaping Ability. *Processes* **2024**, *12*, 267. https://doi.org/10.3390/pr12020267

Academic Editor: Hideki KITA

Received: 5 December 2023
Revised: 21 January 2024
Accepted: 23 January 2024
Published: 26 January 2024

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1. Introduction

The catalytic enhancement technique, manufacturing technology, and specialization are preferred for showing the material characteristics and shaping artistry in shape manufacturing technology [1]. The manufacturing process is a manifestation of shaping and material technology. It can preserve, reflect, and promote cultural awareness. Therefore, for sustainable cultural protection, the characteristics of different places should be expressed as end products [2]. The material technology, creativity, and technical level of manufacturers can be maintained based on the manufacturing process knowledge. Diverse methods have been adopted to strengthen the learning pipeline for beginners [3]. The learning environment for these processing technologies and manufacturing processes can be a training location for investigation, reshaping, dialogue, and exploration [4]. Clay shaping has a rich history and contains many thresholds and restrictions on material knowledge and production skills. It represents the development potential of technological innovation and

manufacturing technology from the perspective of the evolution of materials, catalytic enhancement, and manufacturing technology [1,5]. It can be regarded as an example of integrated process optimization and process control, catalytic enhancement, manufacturing technologies, and the technological process [6].

This study attempted to establish the key success factors in the soil-shaping ability and visual optimization of 3D forming. It explored the key factors of soil-shaping performance during the design and manufacturing process, aiming to build key factor indexes of the soil-shaping ability and visual optimization of 3D forming. The research aims were as follows: (1) discuss the key factors in the shaping ability and visual optimization of 3D forming and identify the important factors that affect the production process; (2) construct the content and dimensions of the shaping ability and visual optimization of 3D forming; and (3) discuss the reference indexes of the shaping ability of the manufacturing method and technology in order to help subsequent users and researchers master the shaping performance and optimize the quality, in the production process, of the forming ability and visual optimization design of end products.

2. Materials and Methods

2.1. Manufacturing Process and Forming

2.1.1. Soil-Shaping Materials

The use of clay soil dates back to the earliest human civilization. Early humans used this natural substance to create many products that improved the quality of life. Today, clay soil is still a valued medium of expression [7]. Craftsmanship is a broad field that integrates traditional manufacturing techniques and artistic beauty to form concepts [8,9]. Therefore, from ancient times to the production of modern clay products, designers have innovated in technology and scientifically integrated technological innovation with culture, gaining an in-depth understanding of science and technology, artistic beauty, ceramic craftsmanship, and the production process(es). These production technologies are reflected in the creators' works in terms of form, technology, function, and style. Through continuous experimentation, their technology and the ideology of the production process are integrated to form three-dimensional clay products [10]. The evolution of clay products over the years is due to their manipulation flexibility, from organic to geometric or from decorative to sculptural. This flexibility determines their original expression, with a blend of specialized technical details and aesthetic forms [11,12]. However, clay is not merely a substance but a mixture containing various elements. Its basic components are alumina and silicon oxide. Table 1 shows the composition of kaolin. Kaolin is a mineral deposit formed near a parent rock by the decomposition of clay from surface rocks through weathering or hot water. It is generally called primary clay. Table 2 shows the composition of ball clay. Ball clay is a rock that is weathered and decomposed. It is moved away from the parent rock by wind or water flow and is deposited in lowlands or lakes. Clay generated after a long period of decomposition and biological decomposition is generally called secondary clay [13,14].

Table 1. Kaolin composition.

Place of Origin/Components	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	K_2O	NaO	Ig.loss
Cornwall (Britain)	46.54	30.08	0.68	0.05	0.14	0.23	1.03	0.06	12.7

Table 2. Ball clay composition.

Place of Origin/Components	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	K_2O	NaO	Ig.loss
Schio (Italy)	67.54	15.79	1.17	0.34	1.11	0.29	4.27		5.50

The material properties of soil-shaping products play an important role in production, including design elements, such as the ability to control visual aesthetics like shape, form, color, decoration, and texture. Moreover, these properties enable designers to produce quality products. The knowledge and learning process and experience of the subject, the scope of analysis, creative thinking, sketch composition, soil shaping, and soil types can help designers continuously improve their skills, knowledge, creativity, material experiments, and technologies. Optimization research has been carried out and production indexes have been developed according to consumer or customer needs [15]. Therefore, this process can enable designers to create products that conform to general social tastes and quality control requirements. They can also innovate the production of clay products through design elements, providing a reference for designers to expand in the field of clay design [16]. Quality and stable materials can produce better products and may enable the local product manufacturing industry to grow and attract new designers [17,18]. Figure 1 shows the appearance of various soil types, including porcelain clay, clay, and black soil.



Figure 1. The appearance of various soil types.

2.1.2. Forming Ability

Clay soil characteristically yields to pressure. It can be of any shape when the pressure is removed, called "plasticity". Plasticity is a property that allows the material to deform under the influence of external forces without cracking or breaking and to keep its new shape when the deforming force is removed. No forming method exists independent of this important basic property [19]. Shrinkage is another property of clay, and it may be counterproductive. Excessive plasticity will lead to excessive shrinkage. This may impact the product during drying and firing. Therefore, the plasticity of clay soil must be controlled. Shrinkage is related to plasticity and occurs during the drying process of clay objects, and it is always associated with the particle structure of clay soil [20]. Figure 2 describes the mechanical die extrusion forming process. (A) Clay input port: properly dried clay is put in; (B) clay-conveying pipeline: the motor rotates the stainless steel stirring blades to push the clay forward; (C) vacuuming facility: the gas is extracted from the clay to make its structure more compact and solid; (D) forming exit: the clay is extruded and formed.

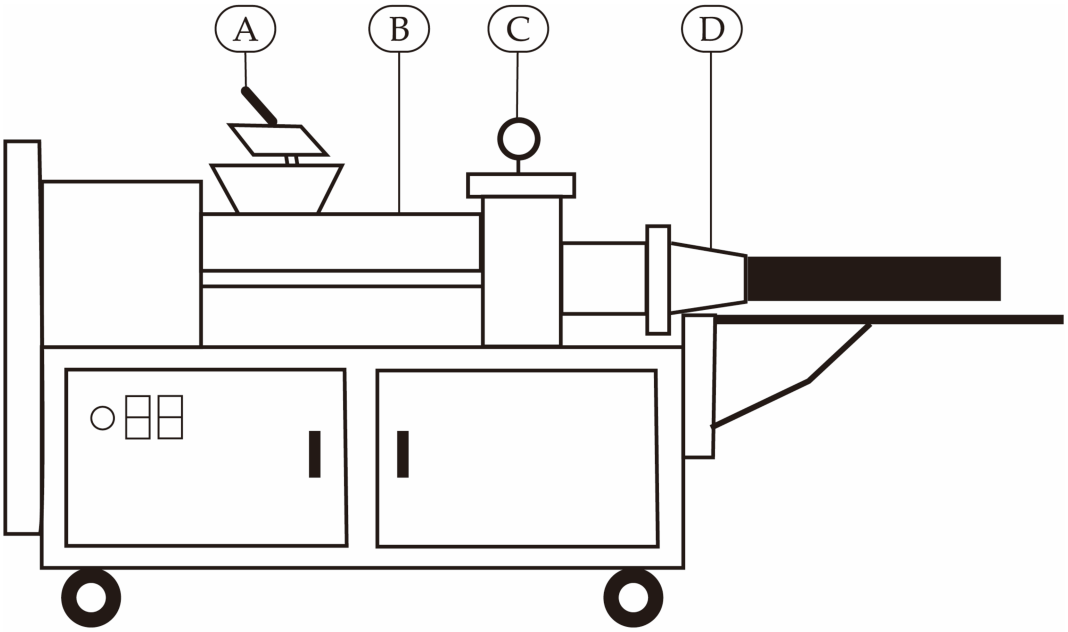


Figure 2. (**A**–**D**) Mechanical mold extrusion forming process of clay.

The above-mentioned forming method is similar to clay 3D printing technology. It is a perfect combination of forming ability technology and modern intelligent manufacturing. This technology is a new method of intelligent clay-shaping manufacturing; however, it retains the weakness of being unable to be completed immediately. In the future, research on materials and modeling processes will be strengthened. Clay-shaping 3D printing technology will improve the design innovation, quality, and economic benefits of 3D shaping design [6,21]. Three-dimensional printing technology also allows new experiences in the contemporary era, which will be placed in the center of the environmental space. It is presented in visual form, effectively demonstrating the spatial structure of the finished product and the superior performance of clay shaping. With advancements in science and technology, the application trend of polymer materials in soil shaping will be further developed [1].

Clay can be molded, knocked, pinched, thrown, pressed, and stamped. These properties allow makers to express their creative potential within this possible range. Firing is an important stage of the production process, as it is one factor that contributes to the value of ceramic products [15]. Clay soil products cannot be used until they are heat-treated. Firing makes pottery products hard, rock-like, and water impermeable [22,23]. Therefore, from clay making to the final glaze firing, the makers must be involved in the various methods and forming abilities required to produce and create various objects. The required forming abilities of the maker in the manufacturing process include clay strip molding, soil slab molding, pinch molding, clay making, soil mixing, soil formulation, mold making, mold imprinting, plaster grouting, throwing, jigging, hydraulic pressing, trimming and finishing, kiln loading and firing, green-body drying, glazing, assessment of moisture content, and other factors [22,24]. Figure 3 describes the forming process of filling soil mud in a plaster mold: (A) take a dry plaster mold; (B) pour the prepared soil mud into the plaster mold and wait for a few minutes for the plaster to absorb the moisture of the soil mud (so that it adheres to the plaster, because the thickness of the soil mud and the waiting time for pouring into the plaster affects the soil-forming thickness); (C) pour out the excess soil mud; and (D) after gradually drying the soil mud, take out the clay body when it becomes leather-hard. The factors of clay type, moisture content, porosity, tool application, kiln type, sintering temperature, glazing, glass oxidation, glaze melting, glaze type, minerals, expansion, and contraction are the overall performance parameters affecting the quality requirements and forming performance.

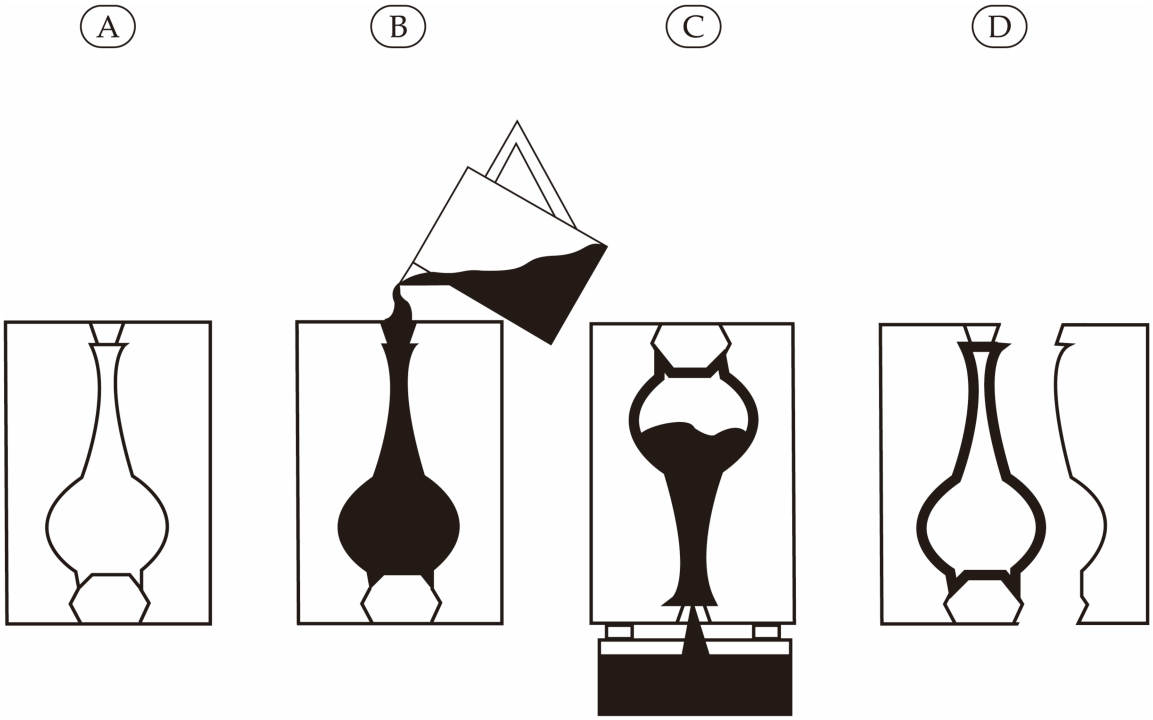


Figure 3. (**A**–**D**) Forming process of filling soil mud into a plaster mold.

2.1.3. High-Temperature Process

Clay is treated at high temperatures, transforming it into a permanent ceramic substance [25]. The high-temperature firing cycle reaches the preset temperature at a heating rate of 100 °C per hour. This heating curve depends on the thickness of the soil mud wall. If the thickness is greater than 2 cm, it is a larger and more complex shape and the firing cycle time will be increased. Figure 4 shows that the biscuit firing temperature in the soil experiment was 800 °C. Figure 5 shows that the glaze firing temperature in the soil experiment was 1230 °C. The composition formula of the transparent glaze is shown in Table 3.



Figure 4. Biscuit firing at 800 °C in the soil experiment.



Figure 5. Glaze firing at 1230 °C in the soil experiment.

Table 3. Composition values of the transparent glaze.

Components	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	K_2O	NaO	Ig.loss
Weight/g	67.54	15.79	1.17	0.34	1.11	0.29	4.27		5.50

2.2. Optimization and Key Success Factors

Optimization refers to finding the best or optimal solution among possible alternatives. It is used in various fields, including mathematics, engineering, economics, and calculator science [26]. Optimal design refers to designing products, systems, or solutions based on maximizing or optimizing certain standards or goals and considering various constraints and limitations. It involves finding the optimal configuration or parameters to attain the desired goals efficiently and effectively [27]. In manufacturing, optimal design may involve designing production processes and workflows to minimize production costs, reduce scrap, and increase production efficiency [28].

Key success factors represent conditions or areas where special and sustained attention must be given to achieve a high level of performance [29]. Finding the key success factors has been important in various fields and process management situations [30,31] and in some research case analyses of innovative product development [32–35]. Among the key success factors in the forming ability of soil-shaping end products and the visual optimization of 3D forming, literature referencing, the material formula, the manufacturing method, and the actual manufacturing process allow us to understand the physical and chemical properties of the material and its formula through the analysis of soil materials and characteristics. These factors allow us to study the performance of the shape and the development of form based on the design conception and conceptual analysis, the mastery of production methods and techniques from the analysis of prototype production, the equipment operation and glaze chemistry from the analysis of the kiln firing process, and the clay shaping and visual optimization design of 3D forming.

Additionally, the dimensions of the evaluation factors are constructed from the soil materials, design concept, forming, the production method, and soil-shaping experiments of firing forming. Figure 6 shows the experimental process.

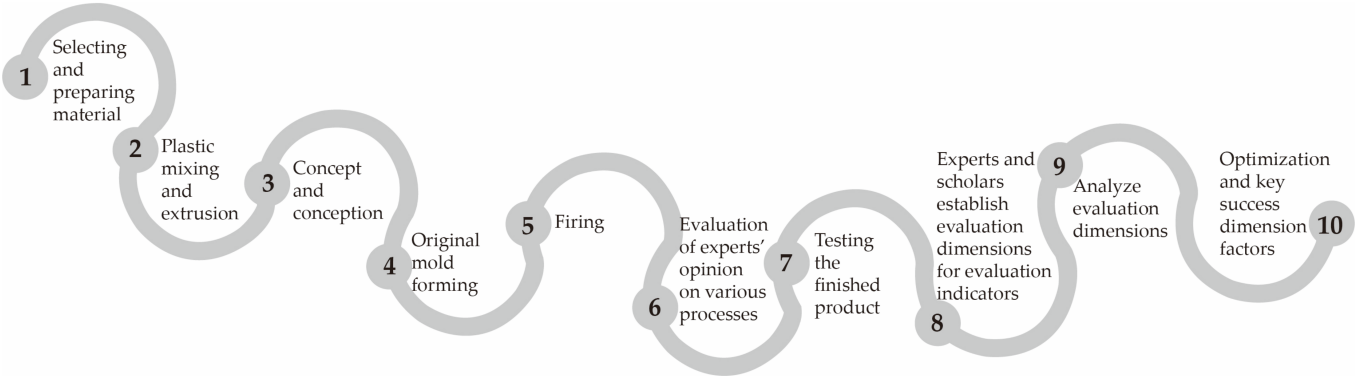


Figure 6. Experimental process of soil shaping.

2.3. Delphi Technique

The Delphi technique was developed to overcome the problem of interacting groups. In this method, the research participants respond in written form, without face-to-face contact. The technique provides significant advantages for the participants. It prevents the domination of individuals with a high status or strong personalities [36,37]. The Delphi method is a popular long-term qualitative prediction technique that has been widely applied to various problems in different fields [38]. To establish consensus among experts and scholars, the standard number of experts and scholars required for the Delphi technique is 10 to 15 [39,40]. The ability to construct and organize group communication has received particular attention [41]. Due to their anonymity, the expert group members can better express their true opinions and positions, leading to more objective opinions and discussions. The collective discussion and joint decision making of experts should result in more comprehensive conclusions than individual outputs [42]. Therefore, the Delphi technique is also a communication structure, aiming to perform detailed critical checks and discussions, and is useful in guiding and predicting trends formed in educational environments [43]. The expert group members fully express concepts or techniques and positions based on their professional knowledge and practical experience, without external influence. Subsequently, the researchers organize, summarize, analyze, and revise the data to construct evaluation dimensions for the next round [44].

3. Experiment and Research Method

3.1. Expert Interviews and Evaluation Dimensions

During the manufacturing and experimental process of soil end products, 13 experts and scholars were invited to participate in interviews. After the product manufacturing experiment, the experts and scholars summarized and organized their opinions based on the content and evaluation dimensions. Finally, the experts and scholars selected the key factors. Based on expert opinion, the evaluation dimensions were analyzed, compiled, and classified [45] and the structure of the preliminary evaluation factors was established [44]. A Likert scale was adopted to evaluate the dimension items.

3.2. Research Structure and Formulation Process

This study discussed the forming ability of soil shaping and the key success factors in the visual optimization of 3D forming. Thirteen experts and scholars were invited to anonymously conduct three Delphi technique evaluation dimensions surveys until a consensus was reached. Figure 7 shows the research structure.

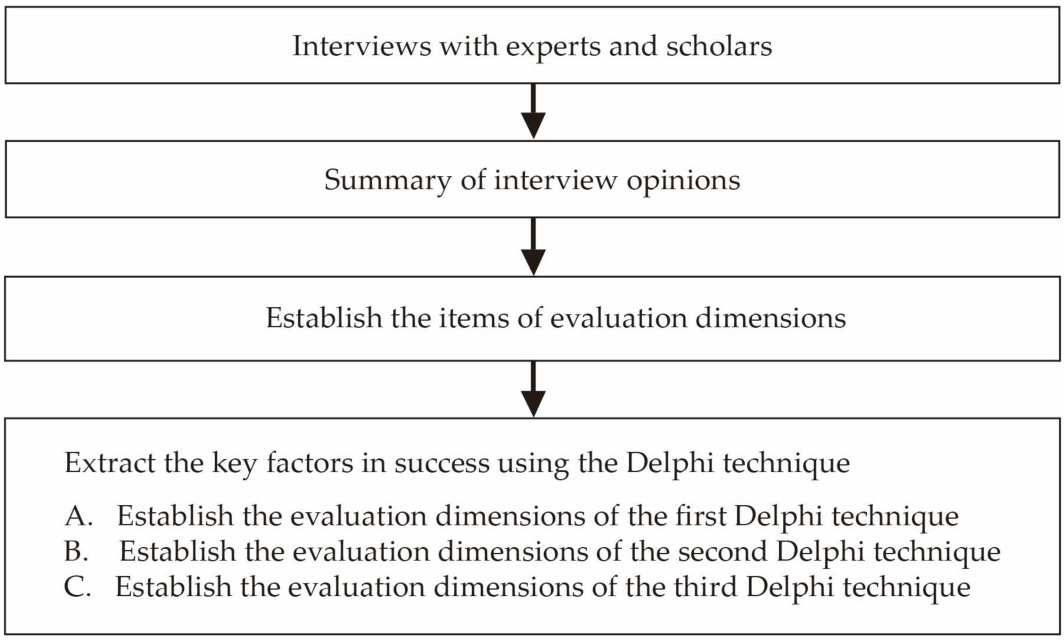


Figure 7. Evaluation dimensions research flowchart.

Selection criteria for appropriateness and consistency in this study [46].

1. Criteria for the appropriateness test:

   Extremely high appropriateness: mean value (M) $\geq$ 4.5,
   High appropriateness: mean value (M) is 4 to 4.5,
   Low appropriateness: mean value (M) < 3.5.

2. Criteria for the consistency test:

   High consistency: standard deviation (SD) $\leq$ 0.5,
   Medium consistency: standard deviation $\leq$ 1,
   Low consistency: standard deviation > 1.

3. Kolmogorov–Smirnov one-sample test:

We evaluated the consistency of the opinions of the experts and scholars (reaching a significance level). We then deleted the inconsistent dimension indexes that did not reach the significance level among the evaluation dimensions [44].

4. Quartile deviation (Q):

The quartile deviation is a measure or indicator to describe the disparity of a group, which is half the distance from the first quartile to the third quartile. If the quartile deviation is large, it indicates the opinions of the experts are more dispersed [47]. When the quartile deviation is lower than or equal to 0.50, the group members have reached a high degree of consistency and consensus, as proposed by Hollden and Wedman [48]. In general, when the criterion of the quartile deviation is lower, the required consistency is higher and it is more difficult to achieve consistency [44].

3.3. Delphi Research Design

The opinions of 13 experts and scholars were analyzed, compiled, and classified. Four dimensions of key factors were formulated. They were: (1) soil material, (2) design concept, (3) prototype process, and (4) kiln firing. The experts' and scholars' opinions were used to obtain the Delphi evaluation dimensions of the 48 sub-dimension items.

According to the opinions and conclusions of the expert interview, 12 sub-dimension items of Dimension 1, "soil material", were formulated, as shown in Table 4.

Table 4. The 12 sub-dimension items of Dimension 1, "soil material".

1-1 Ability to control the soil type
1-2 Soil formula
1-3 Chemical formula
1-4 Silicate minerals
1-5 Plasticity
1-6 Texture
1-7 Shrinkage deformation
1-8 Porosity
1-9 Moisture content
1-10 Mixed soil, color soil, and engobe
1-11 Iron content
1-12 Organic impurities

According to the opinions and conclusions of the expert interview, 12 sub-dimension items of Dimension 2, "design concept", were formulated, as shown in Table 5.

Table 5. The 12 sub-dimension items of Dimension 2, "design concept".

2-1 Theme
2-2 Analysis scope
2-3 Creative thinking
2-4 User experience
2-5 Data collection
2-6 Sketch idea
2-7. Aesthetics
2-8 Shape development
2-9 Decorativeness
2-10 Functionality
2-11 Interactivity
2-12 Sustainability

According to the opinions and conclusions of the expert interview, 12 sub-dimension items of Dimension 3, "prototype process", were formulated, as shown in Table 6.

Table 6. The 12 sub-dimension items of Dimension 3, "prototype process".

3-1 Tool application
3-2 Kneading molding
3-3 Clay strip molding
3-4 Soil slab molding
3-5 Mold imprinting
3-6 Plaster grouting
3-7 Jiggering
3-8 Wheel throwing

Table 6. *Cont.*

3-9 Ceramic 3D printing
3-10 Joint and leather hardness
3-11 Decoration performance
3-12 Green-body drying

According to the opinions and conclusions of the expert interview, 12 sub-dimension items of Dimension 4, "kiln firing", were formulated, as shown in Table 7.

Table 7. The 12 sub-dimension items of Dimension 4, "kiln firing".

4-1 Kiln type
4-2 Sintering temperature
4-3 Formation of glass oxide
4-4 Kiln firing atmosphere
4-5 Glaze-melting mechanism
4-6 Flux
4-7 Expansion and contraction
4-8 Mineralizer
4-9 Type of glaze
4-10 Glazing method
4-11 Color performance
4-12 Integrity

4. Results and Discussion

4.1. Results

According to the research structure, the Delphi survey results were analyzed for appropriateness and consistency. The Delphi survey used the Kolmogorov–Smirnov one-sample test statistical analysis.

In the results of the first Delphi study, (1) the mode was above 4; (2) the criteria for the appropriateness test, mean ≥ 3.5; and (3) the medium criteria for the consistency test, standard deviation ≤ 1 [44]. There were 43 sub-dimensions meeting the three conditions. We deleted sub-dimensions 1-4: ability to control silicate minerals; 1-12: ability to control organic impurities; 2-4: ability to control the user experience; 2-10: ability to control functionality; and 4-8: ability to control the mineralizer. The 43 sub-dimensions meeting the requirements were retained, and the analysis of the second Delphi evaluation dimensions was compiled.

In the results of the second Delphi study, (1) high criteria for the appropriateness test, mean ≥ 4 and (2) medium criteria for the consistency test, standard deviation ≤ 0.68 [44]. There were 30 sub-dimensions meeting the two conditions. We deleted sub-dimensions 1-3: ability to control the chemical formula of the raw material; 1-8: ability to control porosity; 1-9: ability to control moisture content; 2-2: ability to control the scope of analysis; 2-3 ability to control creative thinking; 2-12: ability to control sustainability; 3-5: ability to control mold imprinting; 3-6: ability to control plaster grouting; 3-7: ability to control jiggering; 3-9: ability to control ceramic 3D printing; 4-3: ability to control forming glass oxide; 4-6: ability to control flux; and 4-9: ability to control the type of glaze. The 30 sub-dimensions meeting the requirements were retained, and the analysis of the third Delphi evaluation dimensions was compiled.

The results of the third Delphi study were as follows: (1) high criteria for the appropriateness test, mean ≥ 4.2; (2) high criteria for the consistency test, standard deviation ≤ 0.5;

(3) Kolmogorov–Smirnov one-sample test (K-S single-sample test) reached significance (** $p < 0.01$) [44]; and (4) quartile deviation (Q): if the quartile deviation was lower than or equal to 0.50, the group members had reached a high degree of consistency and consensus [48]. The sub-dimensions failing to meet the three conditions were: 1-2: ability to control the soil formula; 1-10: ability to control mixed soil, color soil, and engobe; 1-11: ability to control iron content; 2-5: ability to control data collection; 2-7: ability to control aesthetics; 2-9: ability to control decorativeness; 2-11: ability to control interactivity; 3-2: ability to control pinch molding; 3-3: ability to control soil strip molding; 3-4: ability to control soil slab molding; 3-8: ability to control wheel throwing; 4-1: ability to control the kiln type; 4-4: ability to control the kiln firing atmosphere (oxidation firing, reduction firing, neutral firing); 4-10: ability to control the glazing method; and 4-11: ability to control color expression. The deleted dimensions and sub-dimensions and results are shown in Table 8.

Table 8. The deleted dimensions and sub-dimensions, and results.

No.	Item	Mo	M	SD	Q	K-S Z-Test	Choice
1.	Soil Materials						
1-1	Ability to control the soil type	4	4.31	0.480	0.5	2.496 ***	Keep
1-2	Soil formula	4	3.92	0.954	1	1.294	Delete
1-5	Plasticity	5	4.85	0.376	0	3.051 ***	Keep
1-6	Texture	4	4.23	0.439	0.25	2.774 ***	Keep
1-7	Shrinkage deformation	5	4.77	0.439	0.25	2.774 ***	Keep
1-10	Mixed soil, color soil, engobe	5	4.08	1.038	1	1.664 **	Delete
1-11	Iron content	5	3.92	1.115	1	1.387 *	Delete
2.	Design Concept						
2-1	Theme	5	4.69	0.480	0.5	2.496 ***	Keep
2-5	Data collection	4	4.0	0.913	0.75	1.572 *	Delete
2-6	Sketch idea	4	4.23	0.439	0.25	2.774 ***	Keep
2-7	Aesthetics	5	4.0	1.155	1	1.664 **	Delete
2-8	Shape development	5	4.69	0.480	0.5	2.496 ***	Keep
2-9	Decorativeness	5	4.0	1.000	1	1.387 *	Delete
2-11	Interactivity	4	3.54	0.967	0.5	0.740	Delete
3.	Prototype Processes						
3-1	Tool application	4	4.31	0.480	0.5	2.496 ***	Keep
3-2	Kneading molding	5	4.15	0.987	0.75	1.664 **	Delete
3-3	Clay strip molding	4	4.08	0.954	0.75	1.572 *	Delete
3-4	Soil slab molding	4	3.85	0.899	0.75	1.294	Delete
3-8	Wheel throwing	4	4.08	0.954	0.75	1.572 *	Delete
3-10	Joint and leather hardness	5	4.69	0.480	0.5	2.496 ***	Keep
3-11	Decoration performance	4	4.31	0.480	0.5	2.496 ***	Keep
3-12	Green-body drying	5	4.69	0.480	0.5	2.496 ***	Keep
4.	Kiln Firing						
4-1	Kiln type	5	4.23	1.013	0.75	1.941 **	Delete
4-2	Sintering temperature	5	4.69	0.480	0.5	2.496 ***	Keep
4-4	Kiln firing atmosphere	5	4.15	0.987	0.75	1.664 **	Delete
4-5	Glaze-melting mechanism	5	4.69	0.480	0.5	2.496 ***	Keep

Table 8. *Cont.*

No.	Item	Mo	M	SD	Q	K-S Z-Test	Choice
4-7	Expansion and contraction	4	4.31	0.480	0.5	2.496 ***	Keep
4-10	Glazing method	5	4.23	0.927	0.5	1.849 **	Delete
4-11	Color performance	4	4.0	0.913	0.75	1.572 *	Delete
4-12	Integrity	4	4.31	0.480	0.5	2.496 ***	Keep

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

4.2. Discussion

There were 15 sub-dimensions that met the three conditions of the third Delphi study. The third Delphi study was more reliable and valid than the second. After three Delphi studies, the third Delphi study adopted (1) high criteria for the appropriateness test, mean ≥ 4.2; (2) high criteria for the consistency test, standard deviation ≤ 0.5; (3) Kolmogorov–Smirnov one-sample test (K-S single-sample test), which reached a consensus of opinions among the experts and scholars; and (4) sub-dimensions of evaluation dimensions with asymptotic significance that reached the ** $p < 0.01$ significance level. This study's evaluation dimension analysis aligned with the analytic standard of formulating the third evaluation dimension. The forming ability of soil shaping and the key success factors in the visual optimization of 3D forming could be obtained. There were four main dimensions and 15 sub-dimensions, as shown in Table 9.

Table 9. The four main dimensions and 15 sub-dimensions.

No.	Item	Mo	M	SD	Q	K-S Z-Test	Choice
1.	Soil Materials						
1-1	Ability to control the soil type	4	4.31	0.480	0.5	2.496 ***	Keep
1-5	Plasticity	5	4.85	0.376	0	3.051 ***	Keep
1-6	Texture	4	4.23	0.439	0.25	2.774 ***	Keep
1-7	Shrinkage deformation	5	4.77	0.439	0.25	2.774 ***	Keep
2.	Design Concept						
2-1	The criteria for the consistency test, standard me	5	4.69	0.480	0.5	2.496 ***	Keep
2-6	Sketch idea	4	4.23	0.439	0.25	2.774 ***	Keep
2-8	Shape development	5	4.69	0.480	0.5	2.496 ***	Keep
3.	Prototype Processes						
3-1	Tool application	4	4.31	0.480	0.5	2.496 ***	Keep
3-10	Joint and leather hardness	5	4.69	0.480	0.5	2.496 ***	Keep
3-11	Decoration performance	4	4.31	0.480	0.5	2.496 ***	Keep
3-12	Green-body drying	5	4.69	0.480	0.5	2.496 ***	Keep
4.	Kiln Firing						
4-2	Sintering temperature	5	4.69	0.480	0.5	2.496 ***	Keep
4-5	Glaze-melting mechanism	5	4.69	0.480	0.5	2.496 ***	Keep
4-7	Expansion and contraction	4	4.31	0.480	0.5	2.496 ***	Keep
4-12	Integrity	4	4.31	0.480	0.5	2.496 ***	Keep

*** $p < 0.001$.

Figure 8 is a fishbone diagram of the results. The results of this study provide another channel for discussion and development direction for researchers. The control abilities of the above-mentioned 15 sub-dimensions can influence the soil-shaping ability and performance of the visual optimization of 3D forming.

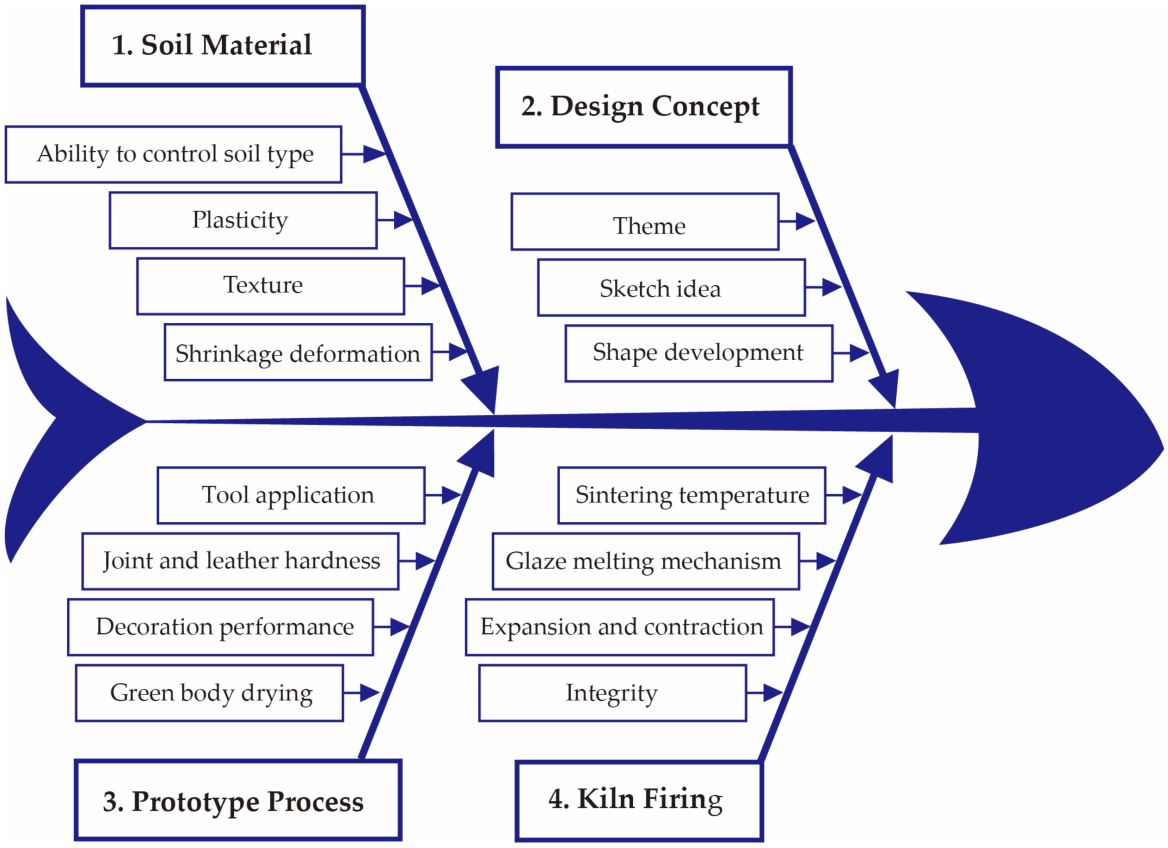


Figure 8. Fishbone diagram of this study.

5. Conclusions

Soil-shaping ability has been enhanced using production technology, and users or consumers can identify the visual effect of complete, mature, and optimized quality. This study used the Delphi technique to test the forming ability of multi-stage soil shaping and the key factors in the visual optimization of 3D forming. Scholars and experts analyzed and summarized the forming ability of soil shaping and the key factors in the visual optimization of 3D forming. There were four main dimensions: (1) soil material, (2) design concept, (3) prototype process, and (4) kiln firing. In the four main dimensions, the statistical analysis results found 15 sub-dimensions meeting the required level for the appropriateness and consistency of the design elements. The 15 sub-dimensions of the key factors in the end product's shaping performance and forming ability and the visual optimization of 3D forming are as follows: (1) the ability to control the soil type, (2) the ability to control plasticity, (3) the ability to control texture (can increase the value of the material and visual quality), (4) the ability to control shrinkage deformation, (5) the ability to control the design theme, (6) the ability to control the sketch idea, (7) the ability to control shape development, (8) the ability to control tool application, (9) the ability to control joint and leather hardness, (10) the ability to control decorative expression, (11) the ability to control green-body drying, (12) the ability to control the sintering temperature, (13) the ability to control the glaze-melting mechanism, (14) the ability to control expansion and contraction, and (15) the ability to control integrity.

The important correlation, contribution, and value of the 15 key success factors for the visual optimization of the 3D forming of soil-shaping ability can be explained by classifying the four main dimensions of this study.

(1) The main dimension of soil material includes the ability to control the soil type, the ability to control plasticity, the ability to control texture, and the ability to control shrinkage deformation. The four sub-dimensions are important control abilities for material knowledge and conditions encountered during actual operations, starting from understanding the characteristics of different soils and suitable production procedures. When the clay is shaped, the treatment of the surface texture of the product causes differences in particle size, porosity, roughness, or fineness during the drying process. Uneven thickness of the clay causes inconsistent pulling of the green body during shrinkage, which is likely to induce cracks and explosions of the green body. Therefore, the control ability of the four sub-dimensions in the main dimension of soil material can enhance the visual optimization expression of product shaping and increase product success in the production process.

(2) The main dimension of design conception included the ability to control the design theme, the ability to control the sketch idea, and the ability to control shape development. These three sub-dimensions are critical factors for observation and practice. They can effectively create product development and production purposes and can be used to enhance the creative expression ability of body shaping.

(3) The main dimension of the prototype process includes the ability to control tool application, joint and leather hardness, decorative expression, and green-body drying. These four sub-dimensions are extremely important control abilities in the production process and are necessary to effectively use various processing, auxiliary, and self-made tools during shaping to meet the need for rigorous and neat production methods. In addition, soil shaping requires skill and experience. In particular, the thickness and dryness of the clay should be considered at the time of bonding. If the clay is too dry, the soil shrinkage time will be too short after bonding and cracks are likely to occur at the joints. Conversely, if the clay is too wet, the clay is likely to shrink for a long time. It can collapse and deform. Therefore, the soil cannot be too dry or too wet. At this stage, the texture and touch of the soil's surface are like leather, called leather hardness. Before leather hardening, the moisture content in the clay is relatively high. This moisture content helps make processing steps like engraving, inlaying, twisting, painting plastic, and other surface decorations easier. Conversely, processing will likely fail if the clay's moisture content is too low. Therefore, the control abilities of the four sub-dimensions in the main dimension of the prototype process can reduce failures and increase the manufacturing yield of shaping.

(4) The main dimension of kiln firing includes the ability to control the sintering temperature, the glaze-melting mechanism, expansion and contraction, and integrity. The four sub-dimensions are extremely important control abilities for the effect of chemical heat treatment and product integrity. The chemical changes caused by heat treatment of clay at over 1200 °C enhance the green body's safety and the glaze color. Differences in shrinkage during high-temperature firing will cause glaze flaking, meaning there will be cracks on the surface of the glaze. Therefore, the control abilities of the four dimensions in the main dimension of kiln firing can increase the visual optimization performance of the product in the space.

Author Contributions: The authors all contributed meaningfully to this study. F.-C.S., research topic; F.-C.S. and C.-J.T., data acquisition and analysis; C.-J.T., methodology support; F.-C.S. and C.-J.T., original draft preparation; F.-C.S. and C.-J.T., writing—review and editing; F.-C.S., C.-J.T. and S.-H.C., discussion and revision of review comments. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: Data are contained within the article.

Conflicts of Interest: The authors declare no conflicts of interest.

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