

Research Article

Innovative Development of Egg Carving Cultural and Creative Products Using 3D Printing Technology Based on Internet of Things

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3D printing technology is becoming increasingly popular in the automotive, electronics, and healthcare industries, to name a few, and the IoT can play an important role in ensuring quality control by connecting big data analytics to 3D printing through the strategic use of embedded sensors. The purpose is to integrate 3D printing technology with intangible cultural heritage-related cultural and creative products in the new era background, so as to achieve the double effects of economic benefits and cultural heritage. The connotation, characteristics, and types of egg carving handicraft are taken as the theoretical basis, and the innovation and development of egg carving cultural and creative products in Linxia city, Gansu Province, are taken as an example. Then, the innovation of egg carving handicraft technology is put forward, including the innovation of technique and expression form. On this basis, 3D printing technology is used, the hollow egg carving model which combines the characteristics of Gansu Linxia egg carving is designed, and 3D solid printing is carried out. The results show that the surface of the eggshell is not too bright and the effect is very subtle. The dark color of the eggshell can well set off the white font and white picture, and the calligraphy and knife method can be integrated and unified. The 3D modeling image of egg carving reveals that the selection of color and material can set off a better viewing effect. Moreover, the 3D printed hollow egg carving works have complete appearance and high artistic design, which has strong artistic effect and is in line with the special color of Gansu Linxia egg carving. Therefore, the strategy of innovative development of egg carving cultural and creative products based on 3D printing technology has a promoting effect on the inheritance and development of intangible cultural heritage of Linxia egg carving in Gansu Province.

1. Introduction

Egg carving is one of the intangible cultural heritages in China. It has strong Chinese color and traditional artistic style and belongs to the combination of art and technology of egg carving artists [1]. As a purely handmade work of art, egg carving has a long history. In foreign countries, the first colored egg was born in 1844. Since then, it has been highly respected in Europe. One of the themes of Easter every year is colored eggs. As early as 600 B.C., Guan Zhong, a statesman and thinker of Qi State in the spring and autumn period, once advocated “carving eggs and then boiling.” In recent years, egg carving has gradually emerged in China. Egg carving works frequently appear in some large-scale national exhibitions and have won many awards. They are

not only recognized by experts but also more and more favored by people. Moreover, egg carving art also begins to appear in some large-scale auctions in China and foreign countries, favored by collectors [2, 3].

Egg carving, as an art of the Chinese nation, has had an increasingly greater impact in the exhibition and exchange in China and foreign countries. Most of the egg carving art abroad are Easter eggs. In recent years, people combine the luxurious style of decorative eggs with folk painted egg art, forming a unique innovative style of decorative eggs popular in Europe and America. China’s egg carving art has gradually flourished, but unlike other art forms, it is still a popular art, and there are few outstanding innovative egg carving works in the market. As an intangible cultural heritage, it is also recognized by more and more people in

the form of cultural and creative products [4]. To study the inheritance of egg carving technology and the innovation of cultural and creative products is not only to inherit the original egg carving technology in a fresh state but also to continuously innovate and develop the technology on the original basis, so as to make the egg carving level rise to a higher level and improve the artistic grade, artistic value, and artistic appeal of egg carving. In this way, the world can know more about the artistic charm of egg carving, an intangible cultural heritage, and the intangible cultural heritage can be further promoted into contemporary people's life, so as to better inherit egg carving technology, an intangible cultural heritage protection project [5, 6]. In order to carry out the innovation of egg carving cultural and creative products, modern technical means must be used. The rapid development of 3D printing technology is a challenge for artists, but it will also promote artists to constantly understand and explore other disciplines and unknown fields. With 3D printing technology as a reference, details can sometimes become another experience for sensitive creators. 3D printing technology will bring sculptors new vision, new way, and new feeling of observation [7]. Compared with traditional sculpture, 3D printer has the advantage of processing irregular, complex, and accurate images and can accurately enlarge and reduce the scale. In these aspects, 3D printing technology can replace traditional sculpture technology, saving more time for sculptors to try different schemes in the design stage of sculpture creation [8, 9]. However, there are few studies on the combination of 3D printing technology and egg carving cultural and creative products with local characteristics, and there are few reports on the dissemination and exchange of egg carving art with local characteristics in a modern way.

Based on this, with the egg carving art of Linxia in Gansu Province as an example, the innovation of techniques and forms of expression of egg carving art has been studied. The shapes of egg carvings in Linxia, Gansu Province, are different. The portraits and natural scenery are vivid, lifelike, and beautiful on each eggshell. Through the 3D design of its egg carving art by computer software, the shape, variety, and personalized customization service of products are increased, which provides a new idea for the development of cultural and creative products. Then, it provides reference for protecting and inheriting excellent traditional culture, promoting industrial development, promoting economic growth and sustainable development of related industries.

2. Method

2.1. Handcraft of Egg Carving. Egg carving refers to carving on the eggshells of various birds. It is to use a variety of special tools to carve content on the eggshell through a certain carving technology. It is about the art types of eggs, such as painting, decoration, inlay, sculpture, and other art processing methods, which act on the eggshell, making it one of the most pleasing works [10]. The content of egg carving can be all inclusive, and the theme is closely related to people's production and life. In the way of expression, it integrates sculpture and painting and uses many complex

and changeable carving techniques. According to the light, heavy, slow, and urgent degree of carving force, the depth of eggshell surface changes in different degrees, so that the carving content is concentrated between the eggshell sizes. Because it is purely handmade, it is becoming more and more popular in the world [11].

The egg carving works of domestic egg carving artists can be roughly divided into four types: hollowed out works, relief works, the combination of hollowed out and relief works, and Yin (Yang) works [12]. Table 1 shows the characteristics of the four works.

Figures 1(a)–1(d) are examples of four kinds of egg carving works.

2.2. Innovation of Egg Carving Technology. Like most traditional folk arts, egg carving also faces great challenges. The development of society is very fast. Therefore, if the traditional art cannot innovate and integrate into people's life, it will lose its value. Innovation is for better inheritance, so inheritance must innovate. Without innovation, there will be no characteristics and advantages. Innovation, as the name suggests, is to create and make new things. It has two factors. One is the subject of innovation. In other words, new things must be created through people's efforts. The other is that it should be new and has never been made before. Otherwise, it cannot be called innovation. Innovation is mainly manifested in the following three situations. First, some people have carried out research, put forward their own views, or made their own views. This is a pioneering and basic work. Second, although previous people have learned and done it, they have not finished it, or they are wrong. Some people have conducted the research, discovered, and corrected the mistakes of predecessors and finally succeeded in the research. Third, predecessors have done the research, and they are correct and successful. Some people have made further progress at this level and integrate their ideas into their own research to further improve the research. In order to inherit the egg carving technology and improve the quality and artistic value of egg carving works, it is necessary to innovate the egg carving technology. Egg carving technology has been studied. Based on the original method, the knife technique has been innovated. Combined with a variety of knife techniques, the technical problems have been broken through, and the multilayer carving technology has been innovated. From the simple level of light, dark, and medium color in the past sculpture works to the extremely rich and delicate multilevel at present, it is especially in line with people's appreciation habits and aesthetic taste.

The innovative development of egg carving cultural and creative products in Linxia city of Gansu Province is taken as an example. In order to vigorously develop cultural and creative tourism industry, Ba Fang Shi San Hang are transformed and developed. In order to inherit and protect the intangible cultural heritage of Linxia city, the handicraft museum has been specially set up. The inheritor of Linxia Hezhou egg carving intangible cultural heritage has been invited to set up its own studio. It can not only protect and develop traditional crafts but also provide better tourism

TABLE 1: Characteristics of different egg carving works.

Different works	Characteristics
Hollowed out works	When electric tools are used to drill holes, cutting modeling is adopted, not only for round holes of various sizes but also for hollowing modeling of various geometric shapes, so the manufacturing method is relatively difficult [13].
Relief works	It is carried out on emu eggs and ostrich eggs with thick shells, or in a relatively thin goose eggshell, very shallow relief is performed. It is relatively easy to implement [14].
The combination of hollowed out and relief works	The work is characterized by “delicacy, fine and smooth, elegance, and purity,” showing a certain 3D sense and more artistic appeal [15].
Yin (Yang) works	According to the weight of the knife, different colors are expressed, which makes the 3D sense of the work strong. The performance content includes print, decorative painting, paper cutting, traditional Chinese painting, and sketch style. This work does not dye any pigment, and the relationship between light and shade depends entirely on the color of the eggshell itself [16].

experience for tourists and increase income. Technical innovation and form innovation are studied.

- (1) *Technical Innovation*. One is eggshell micro book carving. There are many authors carving micro books, but most of them are carved on various kinds of jade [17]. There are no micro books carved on eggshells. Therefore, innovation is conducted, and the micro book is applied to the eggshell carving. Micro carving is a kind of fine carving technology. It is characterized by delicacy, which is also the difficulty of micro carving [18]. According to this feature, attention must be paid to the material selection when micro carving is performed on the eggshell, and the eggshell surface should be as smooth as possible. In addition, the tools for micro carving on eggshell are specially processed, which must be small and sharp. It also requires the carver to have the foundation of calligraphy, so as to achieve the perfect unity of calligraphy and knife technique. A lot of experiments are conducted on various eggshells and it is found that micro carving can be carried out on any eggshell. However, for the purpose of not adding any color, it is suitable for micro carving on red eggshell. When micro carving is conducted on the red eggshell, the eggshell surface should be polished first. Otherwise, the effect of micro carving will be affected.

- (2) *Innovation in the Expression Form*. Eggshell surface sculpture process innovation: it is a method of pasting 3D decorative pattern on the object to be decorated. Common techniques are heap modeling, paste modeling, hollow out carving, engraving, and restraint. The clay is mainly made into figures or animals according to a certain way of expression by hand kneading and other methods, or based on the figures or animals, different patterns are carved on them, and finally they are pasted on the body of the utensil [19]. Because of such inspiration, an attempt is made to apply the art of heap modeling to eggshell. First, the pattern designed in advance is carved on the eggshell. Then, with the mud developed by ourselves, through finger kneading, twisting, rubbing, and the coordination of needle, knife, and grate, a 3D pattern paste is formed at a suitable position on the eggshell surface. Finally, it is necessary to color as needed. The red eggshell is more suitable for carving and pasting small

jewelry, so it is used for the display of heap modeling sculpture technology on eggshell surface.

2.3. 3D Design of Egg Carving Art. 3D printing is a rapid prototyping manufacturing technology, which belongs to the digital manufacturing technology with industrial revolution significance [20]. The main process of production is to use computer software to design the product style of 3D processing and then use liquid, powder, and filamentous solid materials to print the product design style layer by layer through 3D printer. 3D scanning technology is used to detect and analyze the shape, appearance, color, and surface albedo of objects or environments in the real world. The collected data are usually used for 3D reconstruction calculation to create digital models of real objects in the virtual world. The application of 3D printing technology in egg carving art is to print out the “egg” shape modeling drawing that has been designed by the designer, so as to obtain the entity. 3D printing has high accuracy. Compared with traditional manual egg carving, egg carving art using 3D printing has significant advantages, as shown in Table 2.

3D design mainly uses SolidWorks to draw, which mainly includes three steps: drawing basic egg shape, drawing sketch, and material wrapping.

The first step is to describe the basic egg shape. The streamline sketch of the eggshell is drawn according to the designed size, and then a complete egg shape entity is drawn by using the rotation and stretch boss command in the feature. According to the eggshell surface, the thickness is designed, and the command of cutting the rotation boss is used to cut out the internal solid part. Finally, the hollow surface similar to the eggshell is obtained. Among them, the height of 3D model is calculated. The intersection of the projected light and the imaginary plane is set to O and F . Then, OF represents the height of the 3D model. The distance between the 3D model surface and the imaginary plane is h . Then, according to the similarity principle of triangles in the imaginary plane, it can be obtained that

$$\frac{s}{l} = \frac{h + OF}{OF}, \quad (1)$$

$$OF = \frac{hl}{s - 1}$$

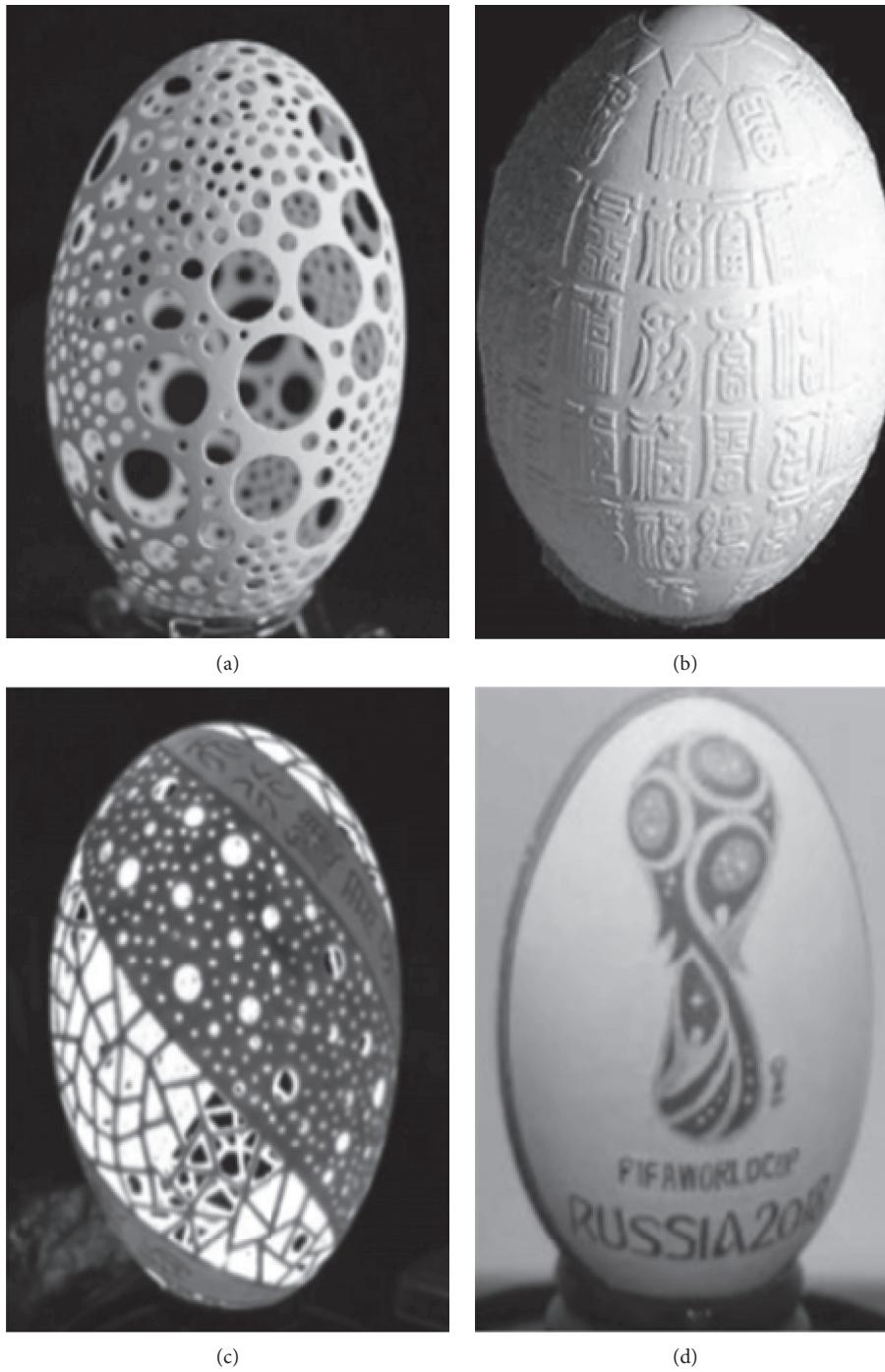


FIGURE 1: Egg carving works of different techniques: (a) hollowed out works; (b) relief works; (c) the combination of hollowed out and relief works; (d) Yin (Yang) works (the images come from the network).

TABLE 2: Advantages of 3D printing egg carving art.

Advantage classification	Main content
High molding rate	After modeling, it only takes a few hours to print out the entity, which is simple to operate and easy to shape.
Short production time	At least 3 finished products can be printed in one day, while the traditional manual egg carving can produce at most 3-4 finished products in one day.
Many kinds of finished products	Computer software can design various patterns and styles.
Personalized customization	According to the requirements, the corresponding design can be carried out.

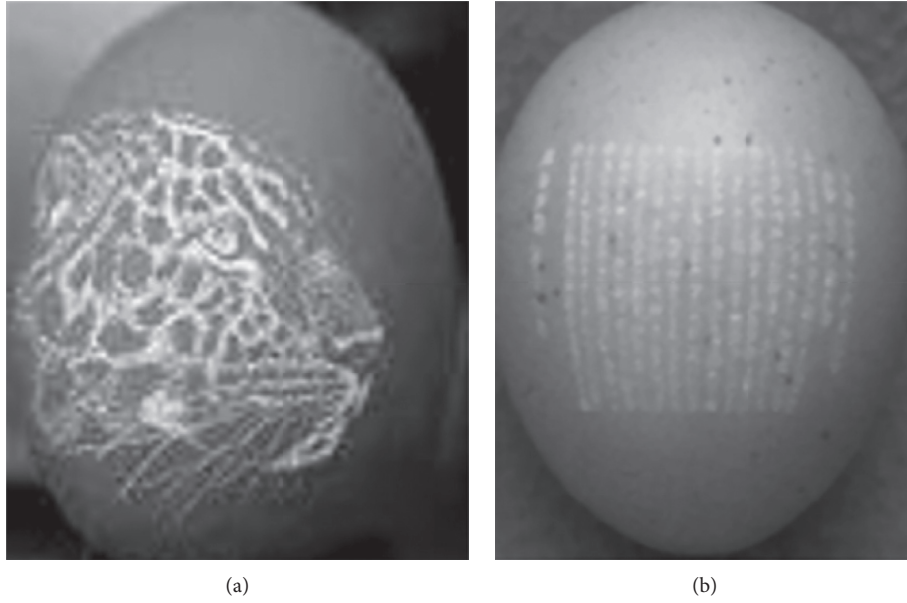


FIGURE 2: Eggshell micro book carving works in Linxia, Gansu Province: (a) front; (b) back.

where s is the triangle area, and l is the distance between the projected light and shadow points.

If the coordinates of the intersection point between the triangle ABC and the tangent plane are set as $E(x, y, z)$, and the coordinates of the triangle vertex are set as $A(x_1, y_1, z_1), B(x_2, y_2, z_2), C(x_3, y_3, z_3)$, the coordinate relationship of the intersection point is as follows:

$$\begin{aligned} \frac{x - x_1}{x_2 - x_1} &= \frac{y - y_1}{y_2 - y_1} \\ &= \frac{z - z_1}{z_2 - z_1}, \end{aligned}$$

$$\begin{cases} nx = \frac{z - z_1}{z_2 - z_1} (x_2 - x_1) + x_1, \\ ny = \frac{z - z_1}{z_2 - z_1} (y_2 - y_1) + y_1, \\ nz = q, \end{cases} \quad (2)$$

where q represents the z coordinate value of the tangent plane.

The second step is to draw a sketch. It is necessary to define the size of the material and draw the sketch on the new datum plane. The commands used include tangent-tangent relationship, curve drawing, isometric solid, and transforming solid.

The third step is to cover the material. Relief and etching commands are used. Relief is to make the solid protrude from the surface of the eggshell, and the etching makes the solid sink to the surface of the shell. At this time, the appropriate coating command should be selected, the part to be sunk shall be selected for etching, and the part to be protruded shall be selected for relief. On the premise of

ensuring beautiful appearance, the difficulty of coating operation is reduced.

3. Results

3.1. Innovation of Gansu Cultural and Creative Products Based on Eggshell Micro Book Carving. Eggshell micro book carving technique is used to make innovative egg carving products in Linxia, Gansu Province. Most of the micro calligraphy works of many micro engravers are running hand and cursive script, because the strokes of running hand are not as complicated as regular script, especially the traditional characters are often used in calligraphy works. Therefore, in order to increase the difficulty of micro book, the font of micro book is regular script. The micro book is depicted on the work of Linxia egg carving, and Figure 2 shows the result.

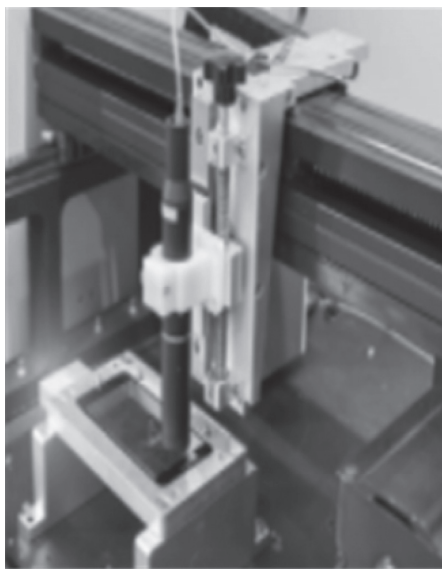
Figure 2 shows that the surface of the selected eggshell is very smooth and not too bright. The effect of micro carving is very subtle. The dark color of eggshell can set off the white font and white picture, which is convenient to watch. It is necessary to use small and sharp tools to carve based on calligraphy, so as to achieve the integration of calligraphy and knife technique. The size of subset in Figure 2(b) is $1 * 1$ mm.

3.2. 3D Printing Modeling Results of Egg Carving. The egg carving based on the hollow carving technique in Linxia, Gansu Province, is modeled in 3D, and Figure 3 shows the result.

In SolidWorks software, after the basic egg shape and sketch are drawn and material wrapping is finished, the rendering function is used to render the drawn graphics. Any material and color can be selected randomly, and it



FIGURE 3: 3D modeling results of egg carving based on hollow carving technique.



(a)



(b)

FIGURE 4: Printing results of 3D printer: (a) 3D printing machine running; (b) 3D printing egg carving entity.

reveals that the selection of color and material can set off the corresponding appreciation value.

Finally, the 3D printer is used for 3D printing, and Figure 4 is the printed material diagram.

Figure 4 shows that the 3D printed hollow egg carving works are in line with the characteristics of Gansu Linxia egg carving, with complete shape and strong artistic effect. Moreover, the beauty of the work is high, which can attract people's attention.

4 egg carving products can be made a day at most when the traditional Gansu Linxia egg carving art is adopted. After

the application of 3D technology, a printer can print at least 3 egg carving products a day. This can efficiently save the production time, and the finished egg carving product is more three-dimensional and eye-catching in appearance, thus achieving the purpose of improving economic benefits.

3.3. Innovation and Development Strategy of Gansu Linxia Egg Carving Cultural and Creative Products. According to the abovementioned 3D design results of egg carving and the technical innovation of egg carving cultural and creative

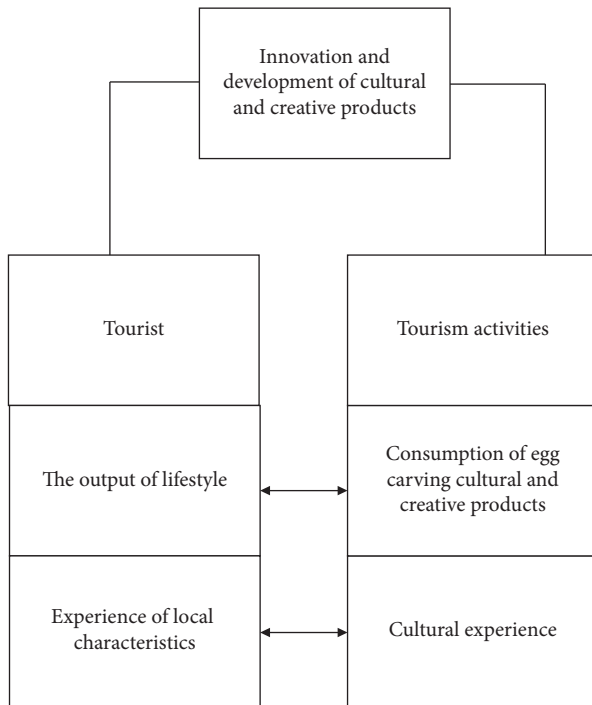


FIGURE 5: Strategy framework for innovation and development of egg carving cultural and creative products.

products, the corresponding innovation and development strategy of egg carving cultural and creative products is designed according to the regional characteristics of Linxia, Gansu Province, as shown in Figure 5.

Figure 5 shows that the development of urban historical and cultural tourism products should focus on regional characteristics and tourist characteristics, and the authenticity of cultural and creative products is the guarantee of product competitiveness. As popular consumer goods, the production of Linxia egg carving is the guarantee of tourism products supply. The balance between localization and egg carving value is the only way for the sustainable development of urban historical and cultural tourism products. Historical and cultural tourism product development in Linxia is still in its infancy. Based on the perspective of economic benefits, the current development is successful. As a successor city, Linxia's development path in the development of historical and cultural tourism products should be innovation based on the imitation of other cities' development path in the past, so as to truly achieve sustainable development.

4. Conclusions

Egg carving art belongs to China's intangible cultural heritage. How to make intangible cultural heritage adapt to the development trend of the new era has become a research hotspot in the emerging technology field represented by 3D printing technology. Based on the concept, characteristics, and categories of egg carving handicraft, the innovation of egg carving technology is proposed, including the innovation of technique and expression form. On this basis, the 3D

design of egg carving art is carried out by combining the regional characteristics of Gansu Linxia egg carving, including drawing the basic egg shape, drawing sketch and material wrapping, and printing the solid egg carving material with 3D printer. The effect of micro book carving is very subtle. The dark color of eggshell can well set off the white font and white pictures, which is convenient to watch, and the calligraphy and knife method can be integrated and unified. The 3D printed hollowed egg carving works have strong artistic effect, and the work has a high aesthetic degree, which can attract people's attention. Hence, the innovation and development strategy of egg carving cultural and creative products in Linxia, Gansu Province, has been designed to enable more people to understand the innovative development of egg carving art in Linxia, Gansu Province, on the basis of ensuring economic benefits, and also enable the sustainable development and inheritance of Linxia's intangible cultural heritage. There are some shortcomings. In the design of 3D printing, there are some deviations in the design parameters of the wrapping effect of egg carving material, which makes the wrapping effect of the modeling drawing material presented poor. Also, when the strategy of innovation and development of egg carving products in Linxia, Gansu Province, is made, there are few contents of reference to national culture, which cannot reflect the characteristics of their national culture. In the later research plan, the parameter adjustment of 3D printing will be strengthened, and the special design of national culture will be strengthened for 3D printing works design.

Data Availability

The datasets used and/or analyzed during the current study are available from the author on reasonable request.

Conflicts of Interest

The author declares no conflicts of interest.

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