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Simulating the Shroud of Turin: A Laboratory Experiment

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Abstract: The Shroud of Turin, a piece of linen cloth bearing an anatomically correct image of a crucified human being, which resembles Jesus of Nazareth, has been an enigma to scientists. While recent studies including radiocarbon dating suggest the cloth is a medieval relic, few if any proposals have been put forward that satisfactorily explain how the image was generated. In combination with a lecture on the scientific method and the problem of bias, a laboratory experiment has been developed that allows science students to attempt to simulate the image on the Shroud. The experiment involves an active-learning experience in which students discover which techniques do not work to generate the image and which begin to suggest how such an image could have been generated.

Introduction

The Shroud of Turin is a linen cloth, approximately 4.3 m long and 1.1 m wide kept in the Royal Chapel of Turin Cathedral in the Italian city of Turin [1, 2]. It bears an anatomically correct image of the front and back of a crucified human being. The figure in the image possesses a beard and long hair gathered into a pigtail, and has its hands crossed over its pelvis as if posed for burial. The image has apparent bloodstains superimposed upon it about the wrists, one side, feet, and head; thus, the image bears a striking resemblance to Jesus of Nazareth after his crucifixion as described in the Christian New Testament. Documentary evidence indicates that the Shroud dates back to at least circa 1389 AD when it was denounced as a forgery by the Bishop of Troyes, Pierre D'Arcis. Intense interest in the Shroud started at the turn of the century when the photographic negative of the image was found to enhance the image, exposing details not previously recognized. In 1978 a team of scientists known as the Shroud of Turin Research Project (STURP) was allowed to examine the cloth using a variety of techniques including a battery of spectroscopic techniques [3–10]. These researchers could not provide an explanation of how the image was formed, were unable to date the cloth or image, and were also unable to rule out that the cloth and image could date to the first century AD [10]. Subsequent radiocarbon dating in 1988 by research laboratories in Oxford, Zurich, and Arizona using accelerator mass spectrometry dated the Shroud between 1260–1390 AD with a 95% confidence [11]; however, proposals that the radiocarbon measurements had been in error or meaningless have often appeared, including in the scientific literature. Such proposals suggest the involvement of unique nuclear phenomena associated with the resurrection of a dead body [12], the enrichment of ^{14}C isotopes during linen manufacture [13], the possibility that the area from which the sample was removed from the cloth contains more recent material as a result of a repair [14], and the effect of microorganisms growing on the cloth [15]. Other than the last proposal, these proposals can either not be tested by science or have been refuted [16]. Claims that the scientists involved possess a religious or other bias have been put forward by scientists claiming a medieval origin of the cloth and by those claiming a first century origin [17]. Still, the procedure by which the image of a resurrected human was generated on the linen cloth remains a mystery.

In combination with lectures on the scientific method and problems of potential bias in scientific endeavors presented in an honors freshman-chemistry course, CH117, at the University of Alabama, the laboratory experiment described herein was developed to allow students to test proposed methods for the generation of the image on the Shroud of Turin.

Experimental Procedures

Students are provided with plastic baby dolls (approximately 35 cm in length), ferric oxide, lemon juice, corn starch, a mortar and pestle, black ink, paint brushes, a hot air gun, and pieces of 100% cotton broadcloth. The scarcity and cost of 100% flax linen prevents its use; most commercially available linen consists of a significant percentage of synthetic fibers. Students are divided into four groups; each group is to attempt to produce an image by a different method. These are: (1) painting, (2) printing, (3) direct transfer with ocher and rubbings, and (4) printing with invisible ink. Other than being provided the supplies and having the basic idea behind each method explained, students are not given further instructions and are allowed to develop their own techniques, making this a self-learning experience.

Method 1. Students attempt to paint the front facial portion of the image on the shroud using ocher (red powder of ground ferric oxide). The pigment may be used dry and applied with a brush, fingers, paper towels, etc. or suspended with water (or water thickened with cornstarch) and applied with similar implements.

Method 2. Students apply ink to the baby doll and transfer the ink (print) by applying the cloth. The cloth may be wet or dry when applied to allow it to conform in different ways to the contour of the doll's body.

Method 3. Students apply ground Fe_2O_3 to cloth draped over the doll. The cloth may be wet, dry, or draped wet over the doll, formed to the doll's shape, and then dried into shape with the hot air gun. Solid may be applied to the cloth by fingers, brushes, or other methods, such as with paper towels, highlighting the areas of cloth contacting the doll (much like a tombstone rubbing). The ferric oxide may also be suspended in water or water thickened with cornstarch and applied in similar manners. Finally, the doll may be covered with Fe_2O_3, followed by pressing the cloth (either wet or dry) against the doll to transfer the solid to the cloth. A number of variations on this theme are also possible.

Method 4. The doll is covered with lemon juice or lemon juice thickened with cornstarch. The cloth, either wet or dry, is applied to the doll to transfer lemon juice to the cloth. Heating the cloth with a heat gun then produces the image.

Lastly, the pieces of cloth are photographed. For the work described below, the prints were then scanned, and prints of the negative were made by Photographic Services of the University of Alabama.

Prior to the experiment, but after attending a lecture consisting of the history of the shroud, proposals on how the shroud might have been produced, and an outline of the methods to be used in the laboratory experiment, students are given the opportunity of proposing other methods to generate images on cloth. Students proposals have included the use of common chemical oxidants such as peroxide, but all such efforts when tested by the author were unsuccessful and were not subsequently used in the laboratory experiment.

Students are then allowed to compare conclusions published by scientific researchers on work related to the Shroud of Turin with the results of their investigation to examine the possibility of bias. This is accomplished by having the students write a description of the methods they tried in the laboratory, including a discussion of what changes they would suggest to get better results and their opinion of the potential for the method to produce a shroud-like image. Finally, a lecture period is devoted to discussing the results of the laboratory experiment and student opinions, including whether or not their results are consistent with literature claims.

Discussion

Numerous suggestions explaining the generation of the image on the Shroud of Turin have appeared in the scientific and related literature, especially after Culliton's review article on the Shroud in *Science* in 1978 [1]. These include transfer from a pre-existing painting [18], scorching [19, 20], primitive photography [21], direct transfer (modeled using linoleum block-printing ink) [22], a wet-mold, dry-pigment technique [23], X-ray radiation [24], and dust drawing [25]. In 1984 Jackson and coworkers [26] attempted most thoroughly to reproduce the image via a wide variety of techniques, including professional artists rendering by drawing or painting, diffusion, direct contact only, radiation from a body shape or engraving, dabbing powder on a bas-relief, impressing a hot bas-relief into cloth, and electrostatic imaging. They concluded that the frontal image on the Shroud is "consistent with a body-shape covered with a naturally draping cloth," and that the generation of the body image and "blood stains" involve different mechanisms [26]. None of the methods examined satisfactorily reproduced the image [26]. A recent review on the Shroud suggests that the image results from oxidative degradation of the cellulose fibers [27]; however, another researcher indicates that the image is red ocher (Fe_2O_3), probably applied as a liquid suspension [28].

This laboratory is designed to test a number of the proposed methods of generating an image on cloth to determine if they are capable of reproducing characteristics of the image on the Shroud. The four methods described above were carefully chosen from proposals in the scientific literature and demonstrate the difficulty of reproducing the image. The first technique, painting, was chosen to demonstrate to students the great difficulty in attempting to simply paint such an image. Students to date have demonstrated a broad range of artistic talent, but none have been able to generate a painting whose negative image possessed the apparent three-dimensional quality of the Shroud. The second technique was designed to test direct transfer [22]; using the baby dolls, students have been unable to generate images of similar quality to that of Nickell who used a human face (not shown). Additionally, the negatives of the images have possessed only limited three-dimensional quality. These images (and their corresponding negatives) are also laterally distorted; this phenomenon was previously described by Jackson and coworkers in their efforts to reproduce Nickell's technique [26] and is also obvious in Nickell's work [22].

In contrast the third method (which uses red ocher to generate a rubbing or the transfer of red ocher from the doll to the cloth) generates images which reproduce qualities of the Shroud image. These techniques are designed to test the wet mold, dry transfer proposal of Nickell [23] and the use of red ocher proposed by McCrone [28]. The most successful technique has been to apply the iron oxide powder to the doll, lay the cloth over the doll, wet the cloth to allow it to settle over the features of the doll, and finally remove the cloth and dry it with a heat gun (because of time constraints). This novel method developed by the students in the laboratory somewhat resembles a proposal for making a cloth drape over an image by wetting [26]. The negative of the best image to date is shown in Figure 1. Lateral distortion is minimized (even the Shroud image contains some lateral distortion [26]), while the image possesses apparent three-dimensionality similar to the Shroud image. The features of the face (note the resolution of the lips, nostrils, eyelids and even small facial wrinkles) are the clearest, as the students used special care in this area. With this resolution using a 35 cm doll, it would appear to be possible to image the features of a human-sized mannequin. Ferric oxide particles in this method (which is distinct from any method in the literature) do not penetrate through the cloth as in the experiments of Jackson and coworkers [26]; however, the positive images generated using this method by the students to date are too dark to properly reproduce the faint Shroud image. Still, if students were allowed to refine their technique and use a human-sized doll in a subsequent laboratory period, lighter images, which would closely reproduce the Shroud image at a macroscopic level, could be generated. Subsequently, the cloth with the lighter image could be examined in instrumental analysis laboratories or laboratories in other higher-level chemistry courses to determine if the image reproduced features of the Shroud image chemically and at a microscopic level.

Finally, the fourth procedure, invisible ink printing, was examined to model an image made of oxidized organic materials, although this case involves the oxidation of the applied material rather than the cloth itself. The presence of an organic binder on fibers in the image areas of the shroud is highly debated [26]. McCrone [28] has reported that some fibers are "cemented" together with a yellowed residue and that a dried film and other accumulations are observable on Shroud fibers at 200–400 times magnification under a microscope. He also indicates that image fibers test positive for the presence of protein. A mechanism involving the yellowing of a binder can be reproduced to a reasonable degree by the "invisible-ink" procedure. In contrast, other workers have reported that at magnifications up to 1000 times no coating can be observed [26, 29], that the tests for protein by McCrone were not accompanied by proper controls [26], and that image fibers display corroded surfaces as expected for "oxidatively degraded cellulosic material" [26]. A proposal on

Figure 1. Negative photographic print of the image produced on broadcloth by applying cloth to a doll covered with red ocher.

how the image could be generated in such an oxidative transformation is vague, however, involving an unknown series of dehydration, condensation, and oxidation reactions [26], with the faster degradation of the image areas by an unknown mechanism. No proposals on how to simulate this degradation, except by X-ray irradiation [24], scorching [26], and an aloe dust drawing [25], have been described in the chemical literature. (For safety purposes, it was decided not to test generating an image using X-rays or by scorching the cloth with a hot object such as a metal figure heated to a few hundred degrees Celsius. Jackson and coworkers [26] have previously shown that the scorching method results in images that penetrate the fibers unlike those of the image area of the Shroud.) The invisible-ink method has only succeeded in producing images in which one can only make out the outline of the shape of the doll; no details except the position of the eyes are observable. In addition to poor resolution, the images are also laterally distorted. The aloe-based method also produced a low-quality image, and its lack of historical relevance was noted [25].

The photographic method of Allen [21], which produces stunning images that closely simulate the appearance of the shroud is too elaborate and time-consuming for a freshman laboratory environment; the possible use of the technique in the 14th century will be a matter for discussion for some time.

Conclusion

The simulation of the Shroud of Turin provides a laboratory opportunity for active learning by students and can be used to enforce the principles of the scientific method. While not establishing how the Shroud of Turin was produced and demonstrating the difficulties inherent in reproducing the Shroud, it still shows that the generation of such an object may not be impossible. Students can compare and contrast their results with the conclusions of scientific experiments published in the literature to examine the potential existence of bias affecting conclusions in scientific research.

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