# An Experimental Study in Fashion Education: Using a 3D Laser Scanner for Body Measurement and 3D Design

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## Abstract

This paper describes an experimental study into the application of 3D laser scanner technology for learning and teaching in undergraduate and postgraduate fashion and textiles design; clothing manufacture, fashion marketing, merchandising and promotion. The study focuses on testing the 3D scanning equipment with a student sample group. The sample group attempts to simulate the range of body shapes that are categorised by the standard size chart specification method currently used in UK fashion education and industry.

The methods applied for evaluation and testing of the 3D laser scanner for body measurement are described, and the results of the initial user experiences are also discussed. The tests seek to establish the overall efficiency of the 3D scanning process and to investigate any potential value for integration of the 3D scanner in fashion/ textiles design education. Conclusions provide further recommendations on the potential effectiveness of connecting 3D body scanning methods to 3D clothing design and construction technology, in an attempt to develop new, integrated learning and teaching methods that positively enhance the future of fashion education.

## 1. Introduction

The paper describes the experimental study for testing a portable 3D laser scanner, for future use in undergraduate and post graduate fashion and textiles courses. The study focuses on the evaluation and testing of the 3D scanner and 3D scanner software with the cooperation of BA (hons) Fashion, with Marketing, Manufacture and Promotion student/staff volunteer group at the University of Huddersfield. Selection of the student volunteer group, attempts to reflect the range of body shapes defined by the standard size charts currently used in fashion and clothing design education and the apparel industry. The experimental study will test the overall efficiency of setting up and operating the 3D laser scanner and 3D software. The study will also investigate the potential value of integrating the 3D laser scanner with 3D CG/CAD software, to extend the research into the areas of wearable technologies.

During the academic year preceding the experiment, a case study was carried out within the School of Art & Design. The case study focused on a final year group of BA (hons) Fashion, with Marketing, Manufacture and Promotion students, and was essential for gathering the preliminary research data neccessary for supporting the experimental study. During the case study, the researcher observed and documented student/staff learning and teaching experiences during fit sessions, and at different stages of design practice in their final major project. Fashion lecturers were informally interviewed on current teaching methods. Fashion students were also interviewed during design development/manufacture practice, on their use of the toile stand, awareness of the body and measurments, 2D/3D traditional design and manufacture processes and 2D/3D Computer Aided Design.

# 2. Background

## 2.1 Anthropometrics

Anthropometry is the practice of measuring the human body (Croney, 1981) Artists, scientists, anthropometrists and tailors have accurately measured the human body with traditional tools, such as tape measures, callipers and accumulated experience for centuries. Pheasant (1986) expands these definitions to ‘applied anthropometrics’, which include numerical data concerning size, shape and other physical characteristics of human beings that could be applied in the design context. Croney (1981) describes a process where both the designer and the ergonomist have a continuing need for up-to-date anthropometric data to model equipment, working situations and clothing for optimal use. Croney (1981) also recommends that static and dynamic anthropometric data will provide the designer with an armature of dimensions around which ideas can grow.

## 2.2 Standard body and garment measurements

Technological developments, patternmaking insights, and mass production changed how clothing was constructed by the early 1900s. Tailors recognized similarities between the garments they made for individual clients, and began to think in terms of proportionally scaled patterns for people of different sizes, known as “graded” sets of clothing sizes. (ExploreCornell, 2005) As a result ready-to-wear is now the principle source of clothing production available to the global mass market. Efficient mass production of clothing requires a method of producing accurate patterns which will fit the ‘statistically average woman’ (Taylor, P.J & Shoben, M, 1986) According to Gray (2000), the production of apparel is dependant on sizing standards, an accurate system of pattern drafting and technology, to permit versatility and quick response. Body measurements have to be obtained through surveys taken manually or with the use of computerized equipment (Beazley, A & Bond, T, 2003) The size charts developed by clothing manufacturers, provide a range of body or garment measurements, divided into categories offering standard sizes suitable for their retail customers. Fan, et al.,(2004) state that each size has a recognizable code; such as 10, 12, 14 or small, medium, large, to assist consumers to choose apparel which fits their body properly.

## 2.3 3D body scanning technology

3D Scanning is a process used to build a digital 3D copy of a physical surface. To assist the spatial analysis of clothing appearance, body measurement and fit, a 3D digitisation of body form and clothing surface is essential. Fan, et al.,(2004)

3D Scanners can be grouped into four main categories: structure light, laser, infrared and photogrammetry. Fan, et al.,(2004) Important methods and considerations relating to technical and application problems often encountered during body scanning/measurement experiments are discussed by Fan, et al.,(2004) Beazley (1997) and Aldrich, et al; (1998) who investigate measuring ergonomic body movement for improved fit in functional clothing. Simmons, L & Istook, C (2003) and Istook, C & Hwang, S,J (2001) describe detailed studies into body measurement and scanning methods, and provide indepth analysis of currently available 3D whole body scanners.

Since the 1980's research in 3D scanning technologies has developed rapidly, increasingly becoming accepted, from research projects to commercial 3D measurment in made to measure apparel, and also for prosthetics and ergonomic devices for the body. Business2.com (2001). Gray (2000) defines body scanning as the best strategy to implement, strengthen and enhance the appeal of made to measure clothing. In 1999 the UK Government, recognised the major impact that 3D body scanners could have on the clothing industry by launching a national research programme called the Centre for 3D Electronic Commerce.Treleaven (2000). 3D technology developments since 2000 have helped to project 3D body scanning into the media spotlight, with several 3D body scanners now in commercial use and being integrated with 3D CAD and virtual try-on technology. Bodymetrics (2001),Bobbin (2001)

Intense media and public interest followed the UK National Sizing Survey (SizeUK) where 11,000 volunteers' measurements were recorded using $TC^2$ 3D whole body scanners. SizeUK (2005) Data results were revealed to the global apparel community in 2003. SizeUK stats (2005). The Bodymetrics (2005) website contains extensive articles describing their progress from early research and development in 2000 to 3D CAD Couture on the catwalk and acceptance on the High street in 2005.

Current academic research using 3D whole body scanners to enhance the curriculum in fashion and clothing universities worldwide, emphasises the extent of acceptance in 3D technologies. Bougourd (2005), Bunka (2005), ExploreCornell (2005)

3D fashion researchers at London College of Fashion are exploring collaborative interdisciplinary projects using 3D technologies and smart clothing/products. Marks (2005),University of the Arts (2005). Specific application of 3D body scanning as a tool for improved construction of smart clothing is described by Nam, et al; (2005) The group use a 3D body scanner to test the fit of Liquid Cooled vests currently worn by astronauts, firefighters, and pilots. The analysis of 3D scan data results will assist in the development of improved fitting functional garments, for a wider performance clothing market in the future.

# 3. Objectives of the study

## 3.1 Outline view of the experimental study

- To test methods for use of a portable 3D laser scanner and 3D software
- To scan a sample sizing group using BA Fashion students
- To collect a range of digital 3D body surfaces for future experiments
- To develop new methods for integration of 3D digital measurement data into 3D technologies for fashion & design education

# 4. Analysis of the 3D laser scanner and 3D software

## 4.1 Non-contact 3D Laser Scanner

The 3D laser scanner is available for students on all courses in the School of Art & Design, and is currently being used mainly by students in 3D Design courses ie. BA (hons) Product & BA (hons) Transport Design. University of Huddersfield (2005)

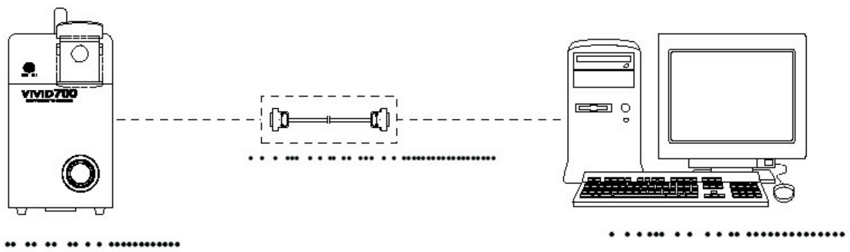


Figure 1 Diagram of a 3D laser scanner, illustrating the connection to PC and monitor

Figure 1 shows a diagram of the 3D laser scanner connected to a PC and monitor, Konicaminolta (2005). The portable 3D scanner captures the surface of an object from a single position. During the experiments the 3D scanner is mounted on a adjustable tripod (See Figure 4) providing versatility, adjustment, variation of positions and stability. The lens of the scanner needs focusing on the object being scanned, and when focused the scanner is simply push button activated. On activation of the scanner, the eye safe, light beam/laser moves across the target object. The laser touches the object and the light is reflected back to the scanner, which captures the surface data of the shape, and records the measurement of an object at a distance between 4 mm or 3 metres.

The measurements are translated into an impact location, and are then displayed by the software as data known as a cloud of points, or cloud data which initially form the 3D shape of the recorded object in the 3D software. (See Figure 2 and Figure 3)

## 4.2 3D scanning software

Geomagic Studio 8 is 3D scanning software for reverse engineering and the mass customisation of any physical product or object to 3D digital model. Geomagic (2005) describe the 3D software as "...ideal for emerging applications such as mass production of customized devices, build-to-order manufacturing, and automatic re-creation of legacy parts....used in industries such as automotive, aerospace, medical devices and consumer products."

The 3D software provides tools for capturing and manipulation of scanned 3D surfaces of objects. Using the portable 3D laser scanner instead of a 3D whole body scanner, makes it necessary to use dedicated 3D scanner software to edit, manipulate and merge the individual 3D surfaces into whole 3D surfaces/3D models. The software interface offers specific 3D surface design tools which take the user through a sequence of surface processing phases; from organising the scanned physical surface data, to surface preparation and composition of accurate models for 3D design and manufacture. Landmark or target points can be added to a surface and measuring tools are available in the software. The body scan surface data is represented as dots termed Cloud data (Figure 2), which can also be displayed as a triangulated wireframe, a wireframe with 3D rendered mesh (Figure 3), or simply as a coloured 3D surface.

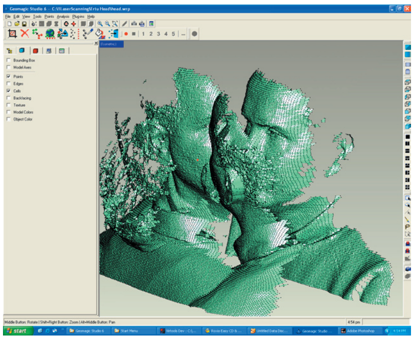

Figure 2

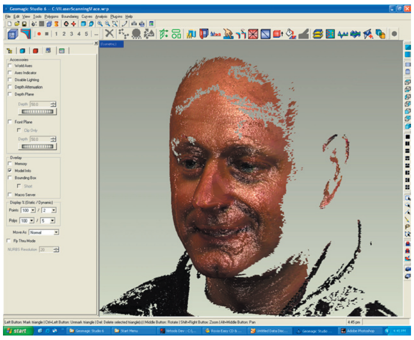

Figure 3

Figure 2: 3D software interface and captured 3D head surfaces as point cloud data
Figure 3: 3D software interface and captured 3D surface data as a rendered mesh

# 5. Discussion of methods used in the experiment

## 5.1 Pre-test methods used in evaluation of the 3D equipment

Exploratory methods were used to test set up of the scanner under different conditions. A series of pre-test head and body scans were taken using the research team as volunteers. Testing equipment without a student sample group is necessary to establish the correct environmental conditions and ensure volunteers are comfortable during the experiment.

The 3D scanner is set up on a tripod, allowing 360º rotation and is adjusted to a height that gives the recorder a full view of the human body. The scanner is quickly and easily connected to a laptop or a PC computer through a SCSI connection. The setup of the scanner and laptop is illustrated in Figure 4.

During the pre-test experiments, a series of evaluation scans are recorded: variety of head positions, normal everyday clothed bodies and bodies wearing personal choice close fitting sportswear were scanned. These pre-tests were carried out to assess the quality of the scan results and performance of the scanner for recording different physical properties. The properties selected for testing were; environment, light levels, distance/depth and range of the laser in the scanner, the quality of colour, textures, fabrics and shapes of surfaces/objects. Early results during the pre-tests highlighted important areas. Sleeveless tops and leggings were made from white stretch Lycra to provide scan volunteer uniformity, comfort and overcome unsuccessful scan results with random volunteer choice of certain types of fabrics/ clothing. The scan outfits were made in three sizes, small, medium and large, intended to cover underwear and closely fit any volunteers' body shape.

Figure 4: Image of the 3D laser scanner on a tripod connected to a laptop

The tests also explored different methods for ensuring each volunteer's body stays static and retains alignment during the 360º rotation. As each scan records a surface, the volunteer must move into eight different angles to record the whole body surface data which proved difficult. A foot position board was made to stand on, eight equal directions were defined and foot positions were outlined for each direction to assist correct positioning.

To allow the scan light to capture areas under the arms and avoid unconcious arm movement during the bodies rotation, two foam blocks were shaped to fit comfortably in left and right side contour of the body. The purpose of the blocks is to support the volunteers' arms in a fixed position, at least 10 cm away from the sides of body, this method also avoids volunteer arm discomfort during the scanning rotation.

## 5.2 Methods for the 3D laser scanner experiment

The 3D body scanning sample group included 3 females and 1 male volunteer. Two of the female students also volunteer to be used as live fitting models in regular fit sessions during development of the final year major project collections.

Several other male and female students from the BA Fashion group were invited to volunteer, especially for the size 14-16 scan model, but were uncomfortable about being scanned. Fortunuately, a female lecturer volunteered to be the size 14-16 model in the sample group. The researcher volunteered to represent the standard size 40'' in menswear size categories.

Ethical guidlines were established to ensure data privacy and protect the scan team, the student volunteers and the University from unexpected problems. During the explorartory research, the SizeUK methods used for confidentiality/data agreements were investigated and customised for the University of Huddersfield. An officially approved document was prepared for all parties to sign their agreement that the 3D body data will be given and used only for educational research purposes .

The experiment, illustrated in Figure 5, was setup in a teaching room, separate from the main fashion studio. All outside windows were covered with blinds, this provided privacy and prevented external light interferance during the scanning process. A hospital curtain/screen was used by volunteers to change into the scanning clothing.

Figure 5 shows layout of the scanning experiment and equipment being used.

# 6. Experimental Study

## 6.1 3D scan data capture and data manipulation methods

The following section describes the methods used for 3D scan data processing in the Geomagic 3D software. These methods can also be categorised into three different phases for processing the scan data from the physical body, to cloud data into exportable 3D NURBS (Non-Uniform Rational B-Spline) surfaces:

- point phase
- polygon phase
- shape phase

The scanner is attached to the computer as described in section 5. The volunteer being scanned is asked to move their feet into the next foot outline on the board.

Eight different separate rotations of body position were made to record enough data to composite the surfaces into a whole 3D body surface. To scan one body in eight different scanning positions takes around 10 -12 minutes.

The recorded scan data file is automatically generated by the 3D software as a 2-5 Mb .wrp file made up from points or cloud data. During the point phase the individually scanned, body surfaces are opened in the software's model manager menu to be assessed for accurate recording quality. The irrelevant background cloud data is then deleted, leaving only the body data in the scene. The next stage in the 3D process uses the manual and global registration tools to associate landmark connection points on to each related scan surface in preparation for the data merging phase.

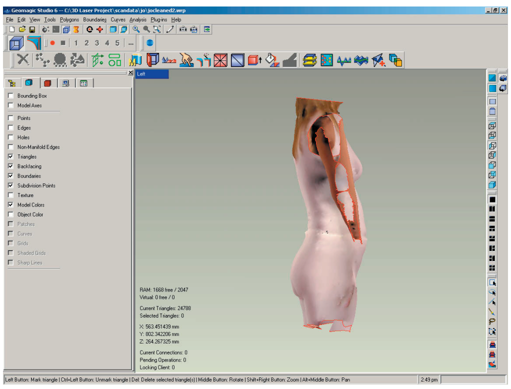

Figure 6

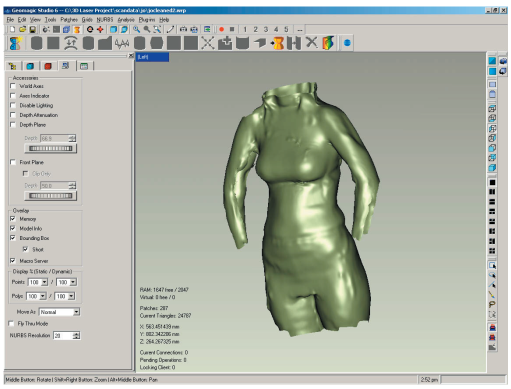

Figure 7

Figure 6: Illustrates Polygon phase of merged surfaces.
Figure 7: Illustrates exportable NURBS surface.

During the polygon phase the prepared 3D cloud surface data is automatically merged by the software and file sizes increase to between 20 -30 Mb. Figure 6 illustrates holes and other irregularities which sometimes occur in the polygons, after the 3D surfaces data are merged. These polygons can be relaxed, cleaned, smoothed and filled to improve the final surface quality of the 3D model/object. In the final shape phase a 3D NURBS surfaces is created shown in Figure 7.

## 7. Results of the study

The preliminary tests found that careful selection and preparation for using the scanning environment is important.  The initial 3D scanner tests on a body, found that human skin, ecru and white matt fabrics reflect light and give highly accurate data.  Darker coloured fabrics absorb all light from the scanner resulting in no data being recorded. Testing the different qualities of fabrics was essential to assess types of fabric or clothing for students to wear during the experiment.  Close fitting Lycra type clothing worn over underwear during scanning allows the 3D laser scanner to accurately record the true body surface.  Hairstyles produced unclear data and long hair can obstruct accurate scanning of face, head, neck and shoulder data.

The selection of student volunteers for the sample group provided interesting data. The pressure of final year course work, uncertainty, reluctance, personal image issues such as body size, shape, exposure of the body shape to strangers and their peer year group, and just general lack of interest, represent some of the student reactions who declined to participate in the experiment.

However, it was found that sampling a smaller, enthusiatic and interested student group helped with focus, cooperation and ensured speed, quality and accuracy of body data results.  An official or legal contract to sign, protecting and reassuring all parties involved in the experiment, ensures ethically approved guidelines are followed and volunteer 3D body data is secure and respected in future experiments.

Scanning the eight surfaces to gather adequate body data takes 10 minutes.  Several methods were developed to ensure correct position, and consistent alignment of the body during each rotation due to the difficulties in keeping all parts of the body perfectly still when being scanned.  Using the foot board was successful, providing a quick, accurate foot position for moving into to record each sequence of body surfaces.

The 3D scanner software provides specific tools to arrange, edit, and optimise the surface data. The surface editing tools used to create a 3D body surface are very logical and precise, and a small time investment is necessary to learn the software. In the early stages of the study processing the 3D surfaces into a 3D body took up to 3 days, this time was improved to between 1-2 hours per body depending on data quality.  Although the 3D laser scanner is much slower compared to a commercial 3D whole body scanner.  The portable scanner has added benefits as it is easy to move, setup, non restrictive, versatile and highly accurate.

When the 3D data is optimised, the software can be used to merge the separate 3D scanned surfaces into a whole 3D NURBS body surface.  The 3D NURBS surface can then be exported to 3D CG modeling and animation software such as Alias Wavefront Maya, 3DS MAX, Cloth FX, Syflex or 3D apparel CAD software such as Browzwear V-Stitcher, Opitex, PAD System, and GerberTechnology.

## 8. Further developments and Conclusions

The experimental study has created the opportunity for fashion/textiles students and academics to use the easily repeatable methods to setup, and apply the 3D laser scanner for scanning 3D surfaces of the human body.

The research incorporated recording and merging the separate 3D body surface data to create a accurate, individual 3D digital body. In the next stages of the experiment 3D scan body data will be input with 2D/3D clothing specific software, and further evaluation of the methods with educational focus groups.

Further improvements for the 3D scanner could be to develop automatic 3D measurment extraction software to link to the scanner and automate the section by section body movement, using a motorised turntable, capable of holding human weight that is connected to a PC and operated by software. The turnatable with a frame would improve volunteer stability, provide consisitant control in the 360º rotation, resulting in higher quality cloud data and reduced time spent in surface processing.

Recommending confidential and respectful use of 3D body data for academic purposes is fundamental to encouraging open use of 3D body scanning for experimental 3D learning and teaching. Research results suggest that the issues surrounding individual body image and body identity is clearly still a concern within education and the public sector. In the near future x-ray scan technology such as the 3D Body Holo Scanner (2005) will record the body, as new combined imaging algorithms, conveniently obtain complete body measurements while the customer remains in his or her street attire. Gadher (2004) highlights public concerns over exposed body images and data privacy and exploitation through enforced use of public space body scanners.

Figure 8 shows the depth of detail in the high resolution scanned 3D foot. Scanning 8-10 sections, at high resolution generates 3 million points of cloud data. The high resolution 3D data can easily be used to create highly realistic animated 3D human models to appear in the cast of CG games, 3D digital television programmes and be used by the CG film industries where consent hasn't been granted. These high levels of resolution shown in the 3D digital scans are not essential for educational or commercial use. Extremely simplified, anonymous 3D wireframe models as illustrated in Figure 9 and Figure 10 will adequately represent the body part or shape and retain original measurements of the student/customer, without revealing their identity or any un-necessary features. The simplified 3D body data will not give any cause for potential embarrassment or hold any value for unethical misuse.

Future work is proposed into the development of new 3D software that will allow instant editing of surfaces from the scanned 3D cloud data. Using this new software it will be possible to also encrypt the 3D data and restrict access to personal information. This development will also enable the scanning, editing and measuring to be combined and reduced to minutes instead of hours.

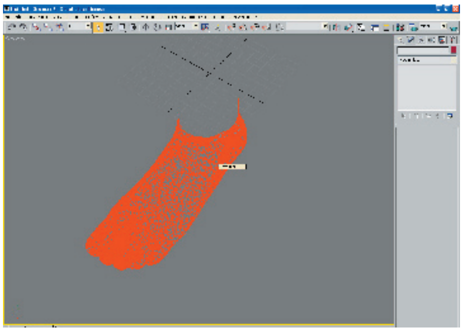

Figure 8 High resolution 3D surface data

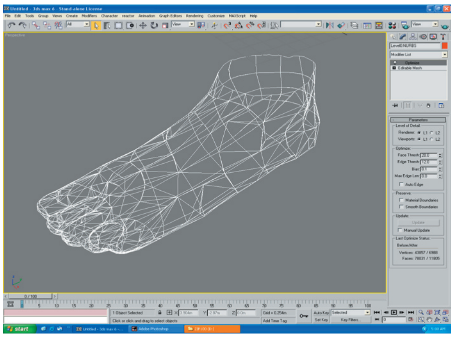

Figure 9 Optimised 3D surface data

Figure 10 Low resolution 3D surface data

Figure 11 3D scanned head provides accurate modelling of wearable product technology

In conclusion to the 3D experimental study, we believe there are extensive of possibilities for integration of a 3D laser scanner in design & art education. Use of the 3D data will clearly enhance made to measure learning and teaching, with 3D-2D pattern cutting and 3D grading being taught on 3D scanned toiles or scanned bodies.

Current research has established that fashion learners need to be introduced to 3D digital technology quickly. Knowing-how to think and communicate in 3D, design using 3D CAD, link to 3D prototyping- 3D manufacture, apply 3D/virtual marketing tools and 3D retail solutions to todays' technology focused apparel industries who are looking to attract todays technological fluent, product and style obssesed consumers are useful vocational skills for the 21st Century fashion student to acquire.

When fashion and textiles students link the inividualised 3D digital body to smart/ intelligent integral products, and then into multimedia/virtual and interior/architecture/ transport and fine art design, the possibilites for innovation are infinate. Exporting anatomically accurate 3D human surfaces or bodies into 3D CG/CAD modelling and animation software as illustrated in Figure 11, to design 3D concepts, prototype component parts and analyse a sample garment or test a products' performance in a 3D simulation, offers an amazing opportunity for fashion design learners, academic practitioners and commercial apparel manufacturers to push the boundaries.

Taylor et al.,(2003) tested user methods for constructing 3D digital garments on imported Poser characters, applying physics simulation tools in 3DS Max and experimenting with 3D cloth plugins.  3D CG software physical world simulation tools could be virtually applied to 3D digital protoype products/models or electronic parts. Then if proved effective the component may be connected to individualised 3D body surfaces to accurately test and simulate integrated, wearable technologies. Evaluating exactly where on the body integral components need to be positioned, assessing how might performance and behaviour of the part be affected or affect the body, in varying simulated environmental conditions is essential to integrate electronics or computers into everyday intelligent functional fashion products.

Encouraging undergraduate 3D awareness through experimentation with contemporary 3D digital design tools like portable 3D scan technology, is vital for digital innovation to emerge.  The 3D design methods we have tested during this study are reproducable and could complement and perhaps help to re-fashion the traditional fashion/textiles teaching methods often being rigidly repeated and followed in FE and HE fashion design education.

Hopefully if opportunities are given to fashion/textiles students to use these methods, and experiment freely with the 3D scanner and with their own 3D data innovation will happen naturally.  By adopting a playful approach when integrating 3D body data with different 3D technologies and design & art subjects, then concepts within fashion/textiles will change even faster than we believe is now possible.  Use of 3D laser scanning and 3D technological tools, can provide real learning experiences for understanding and designing, anything imaginable on, in or around the human body.  Combining this 3D body knowledge, with the vast selection of physical and virtual fabrics and other materials available, can truly create unique and positive opportunities for expanding 3D design and technological innovation further into the future of fashion and textiles.

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