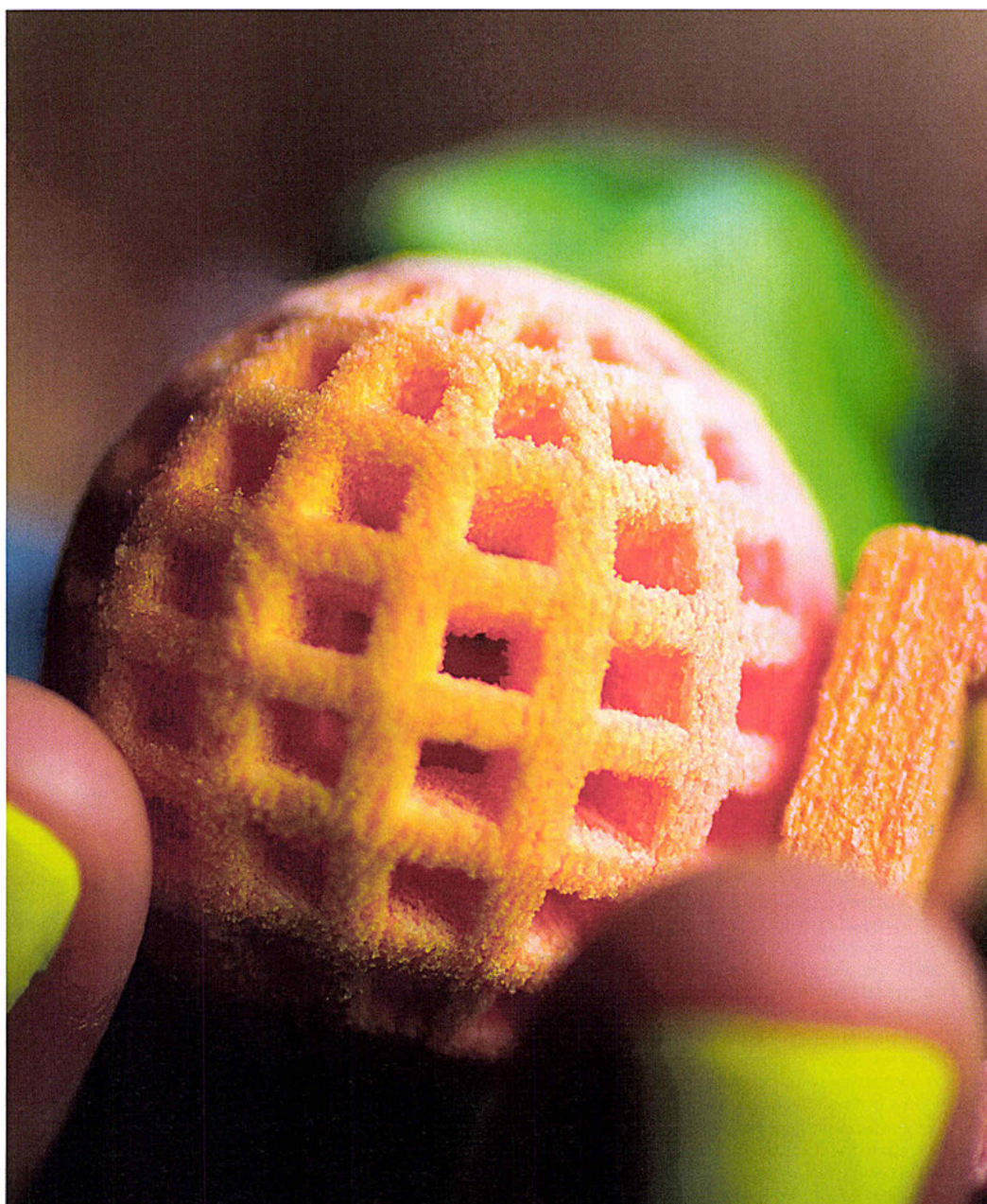




↓ **Made of stone** 3D printing services offer a wide range of materials. Launched this year, 3D Systems' ChefJet Pro prints in edible sugar paste, enabling patissiers to design and reproduce more complex forms than would be possible by hand – even in multiple colours.





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How it's done.



[TRY THIS]

3D printing

Everyone keeps saying you can do it. Last month saw the biggest ever UK trade show devoted to it. But how do you actually design and make 3D objects? With the latest tools, finds Steve Caplin, it's no mystery.

All right, so every year since around 2000 has been the year 3D printing would go mainstream. But as the press hysteria dies down, the reality is quietly catching up to the initial promise. We no longer need to panic about bank robbers outputting plastic guns (they'd be far more likely to injure themselves trying to fire them) or wonder, like one imaginative journalist, 'How long before teenagers start printing their own drugs?' There are now more interesting stories to be told about what's really possible.

For industrial designers, 3D printing is already part of the process, allowing prototyping before committing to mass production and even manufacturing of one-off items that couldn't otherwise have been made. And the rest of us can follow their lead. It's now fairly cheap and easy to rough out any small object on screen,

print it, then continue to modify and output the design until it's perfect.

Working with 3D objects is bound to bring more complexity than we're accustomed to with 2D graphic design and printing, but a lot of progress has been made in simplifying the various processes involved. Just as importantly, the hardware required has been successfully downsized for the consumer market, to the point where you can buy a desktop machine that's as compact and affordable as a business-class laser printer.

'It's getting the next generation of students ready for industry,' explains Aaron Anderson of Printerbase, a retailer of traditional printers that's now selling a range of CubeX 3D models with a three-year warranty. But it's not just for aspiring engineers: anyone can have a crack at it. Although there's a lot to learn,

with plenty of tips available online it's quite feasible to get your own machine and, given some trial and error, teach yourself how to use it.

The alternative is to send your designs over the internet to a 3D print bureau. This inevitably increases the cost per piece, and you'll have to wait for delivery, but there are advantages: besides avoiding the hassle of operating the printer, you'll get a wider choice of materials than is available in desktop machines.

YOU DON'T EVEN have to start from scratch with your designs. Millions of 3D objects can be found online, many of them free of charge. They'll need to be processed before printing, but these days one of the most effective apps for the job is your old friend Photoshop CC, whose 3D print tools have recently [continued on p74]

IMAGE 3D SYSTEMS



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Making it real

What we found at the London 3D Printshow 2014

[continued from p73] been improved again. If you do want to design your own objects, you'll need to consider a CAD (computer-aided design) program.

As daunting as this kind of software can be, several capable apps are available free – see p77 – so you can see if they suit you without penalty.

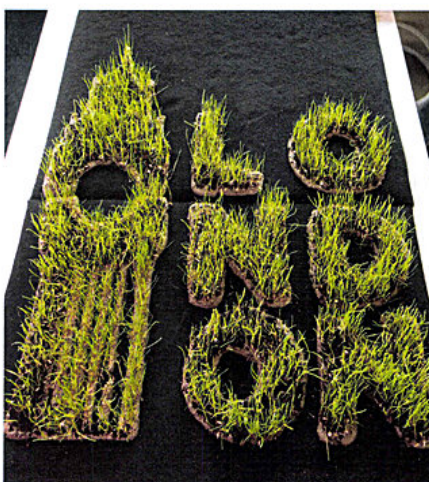
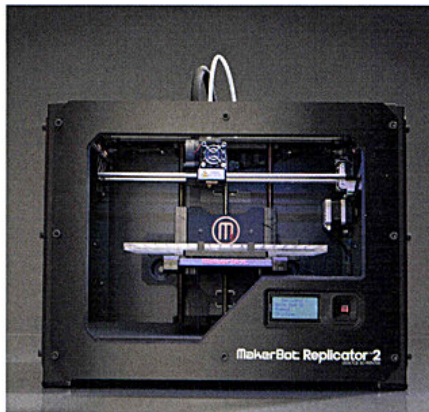
Print your own Almost all desktop printers use the filament deposition method (FDM), which entails reels of coloured plastic wire being fed into the machine where the 'hot end' (yes, that's the official jargon) melts it and squirts it onto the print bed. It's not entirely dissimilar to the way a 2D inkjet printer squirts out ink.

These machines print in either PLA (polylactic acid, a corn starch derivative) or ABS (the stuff Lego is made from). Filament is widely available online, with an average price of £30 to £40 a kilogram. Each model – bearing in mind you can only print at modest sizes – will generally cost just a few pence in consumables.

The most popular desktop printers so far come from MakerBot. But many users reckon the best quality in this price bracket comes from the Dutch firm Ultimaker.

Unlike with inkjets, few manufacturers try to tie you to their own proprietary filament cartridges. An exception is 3D Systems, maker of the CubeX range. Its filament works out at about six times the cost of equivalents from third-party suppliers – something to bear in mind when working out the cost of owning a printer, though not the only factor.

A NEW 3D printer seems to be launched on Kickstarter every month, and prices are still falling: it's now possible to buy a machine from around £300. Bear in mind, though, that 3D output is mechanically very demanding, thanks to the quantity of moving parts and the precision required of them. Going for the very cheapest printer could [continued on p76]



↑ **Maker fair** MakerBot's Replicator is complemented by an app that helps you find models

← **Head space** This skull was made from a scan and marked up to help a surgeon prepare to operate on a bone cancer patient





↑ Hip to be square

3D Systems is a big name in high-end printers, but also makes the relatively affordable Cube range, which – like MakerBot – starts at well under £2,000.

→ Fake plastic tease

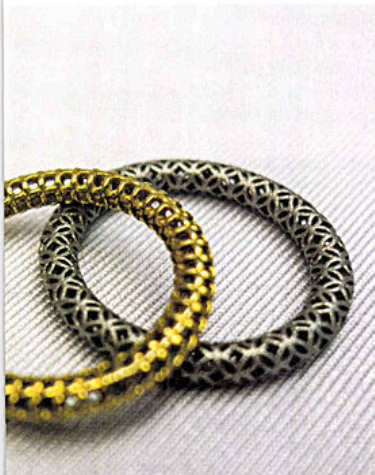
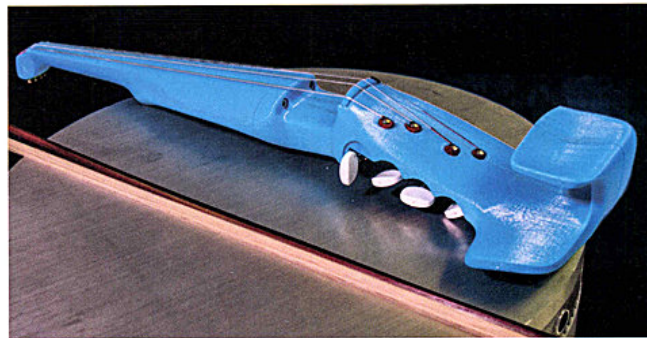
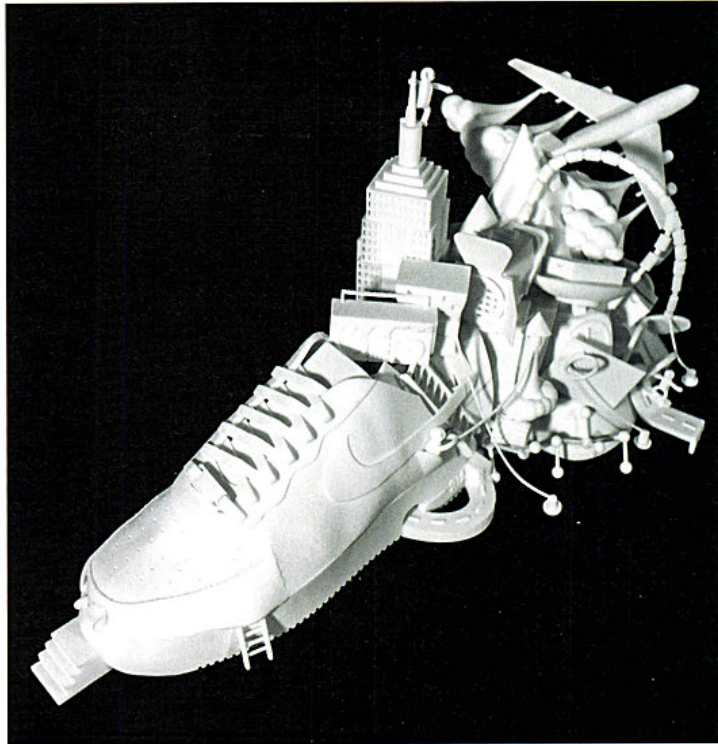
This shoe was created by artist Antonis Kiourktsis. It's effectively a photomontage in three dimensions, a whole new kind of art enabled by printing.

✦ Grassing up

Slovenia's University of Maribor prints a mixture of soil, water and grass seeds, then leaves it to grow naturally.

↓ Go figure

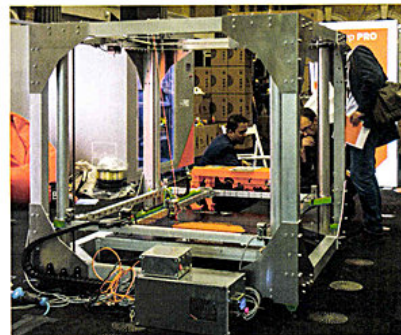
This statue by artist James Stewart shows how 3D printing can release the expressive power of sculpture in a different way from traditional media.



↑ **Third violin** It's possible to print just about anything, even a musical instrument. But the bow is still made conventionally.

✦ **Jewellery box** Designing your own jewellery is an ideal use of 3D. iMaterialise is a printing service that outputs metal objects.

→ **A bigger splash** At the other end of the scale, the BigRep ONE is the world's largest filament-based 3D printer. Other types go further – even building houses.



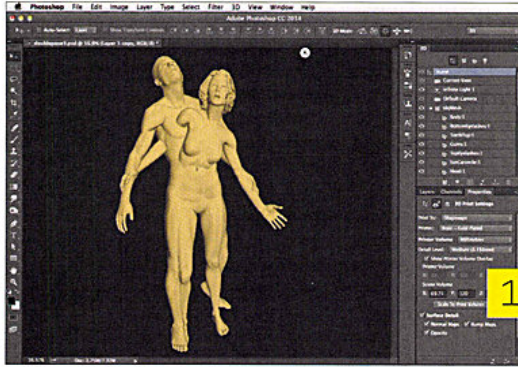
ADDITIONAL IMAGES STEVE CAPLIN



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Correcting a model

MODEL DESIGN STEVE CAPLIN IN POSER

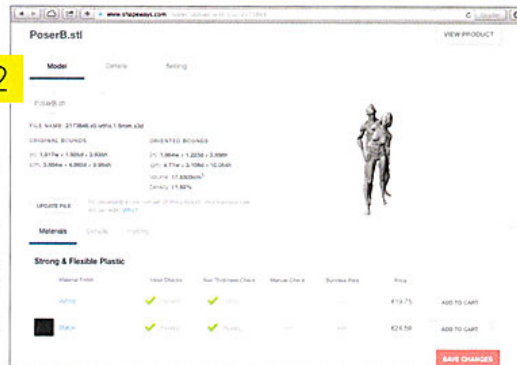


✖ This model of two intersecting figures was created in Poser and brought into Photoshop, where the meshes were automatically repaired, and the model made watertight. But when it was uploaded to Shapeways for printing, errors were reported: those stray hands were too flimsy to be output reliably.



2

→ Back in Poser, we tucked in the hands so that they joined into the bodies, and this second version proved to be more easily printable. Shapeways offers a vast range of materials, from simply plastic to solid platinum.



↑ Our finished model, printed in solid brass. The rough surface seen here is a result of the more basic printing process – a polished gold-plated version would have cost far more to output.

[continued from p74] be a false economy, and with any desktop model you'll need to be prepared to tinker a bit with things when they go wrong.

Having a 3D printer in your own home or office is essential if you want to be able to test out designs or try variations, and it also enables you to produce finished objects as long as they're made entirely from standard plastic. How long things will take to print depends mainly on their size. We printed a replacement toothpick for a Swiss Army penknife, for example, in just a couple of minutes and will cost about three pence; a life-size model of a hand may take five or six hours, at a cost of about four pounds.

Output services There are small-scale 3D print bureaux popping up in most major cities, but most of these use the same desktop machines

you could buy for home use, and so can print only in ABS and PLA. Larger companies such as Shapeways, i.materialise and Sculpteo, which take orders online, can print your designs in a huge range of materials, from basic plastic to precious metals.

These bureaux work with high-end selective laser sintering (SLS) printers, which use lasers to fuse baths filled with powder. 3D Systems is one of the leading manufacturers in this area too. SLS can produce much more detailed models, without the need for support material, but the machinery currently runs to hundreds of thousands of pounds.

That means operators have to charge a good whack to offset the cost of their equipment. The man/woman sculpture seen here would cost €19.75 (about £15.75) to print 10cm high at Shapeways

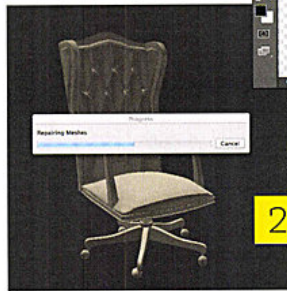
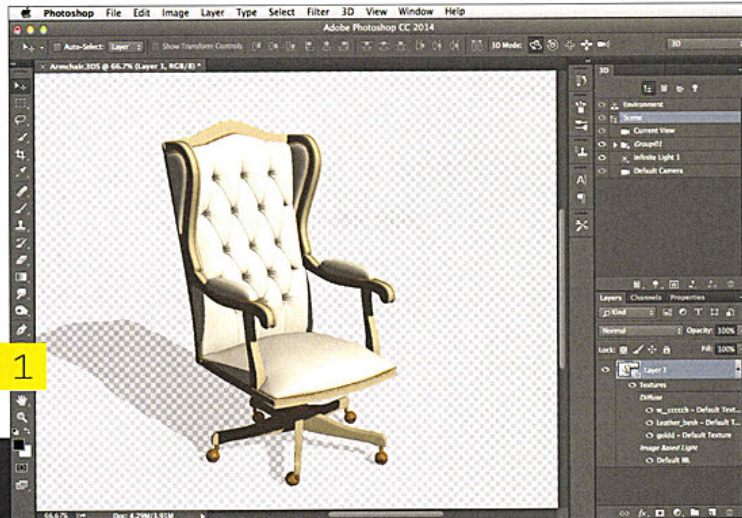
in basic white plastic, or just over €41 (£32.67) in high-detail acrylic. Printing it in steel would cost around €112 (£89.25), rising to €315 (£251) for gold-plated brass or €8,000 (£6,375) for solid 14-carat gold. Not bling enough? You can have solid platinum for €23,000 (£18,325).

ORDERING A PIECE is fairly straightforward, but not yet quite a matter of clicking a button and checking the next morning's post. It'll take two to three weeks to receive your printed model after ordering it, but be aware that pressing Buy Now button doesn't guarantee the file you've uploaded will be printable. Each submission is checked by an engineer before output. The first couple of poses of our man/woman sculpture were rejected, for example, due to too many fine overhanging parts.



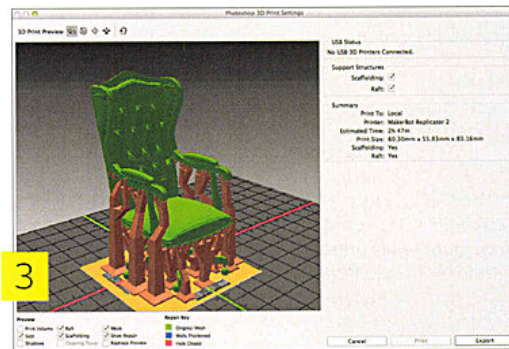
Converting a model

→ We found this model of a chair on archive3d.net, a free repository. Brought into Photoshop, it can be freely manipulated. But it was designed for use in 3D scenes, not for printing.



↑ Photoshop can prepare the model for print automatically, repairing the meshes and making the whole structure 'watertight'. The process usually takes under a minute.

→ Now the chair model is ready to print, complete with a tree-like support structure, marked in brown, to enable the base and arms to print. These additional structures will print, but can simply be snapped off and trimmed afterwards to leave just the intended design.



Most services can also print full-colour objects, which are created in a material that's known as 'sandstone' because of its similarity to that substance. The results can be breathtaking, and models of people, in particular, make very impressive and detailed ornaments.

3D models There are three main ways to get 3D models: you can find them online, scan them from real objects, or design them yourself using a variety of tools.

Thingiverse.com, owned by MakerBot, is the largest repository of print-ready 3D files. These have been designed specially for 3D output and licensed for free use. You'll find everything from thimbles to iPhone cases, skulls to bird houses. It's also a great place to source replacement and improved parts for 3D printers.

For models of everyday objects, try archive3d.net. But keep in mind that these have been collected for use in 3D illustration apps, and not all of them will be printable. Still, you're most likely to find the kind of object you want here. For architecture, 3dwarehouse.sketchup.com offers everything from basic elements to complete models of many of the world's finest buildings.

SCANNING REAL OBJECTS is possible by a number of methods. You can use a dedicated handheld scanner, such as the Cubify Sense at around £340. A cheaper alternative is to pair a Microsoft Kinect sensor, around £85 (get the Xbox rather than the PC version), with the \$129 (£79.25) Skanect app. Skanect also works with the newly launched Structure sensor for iPad, \$379 (£233) from structure.io.

You'll need to move around your object with the scanner, building up the 3D model as you go. This process takes time and patience, requiring you to watch the screen to make sure you have the object centred while at the same time watching the object as you walk around it. Expect a few failed scans before you get it right.

For small objects, a good option is MakerBot's Digitizer (£649), which produces good results for items up to about 15cm in size.

An alternative approach is to use Autodesk's free iOS app 123D Catch. With this, you take 20-odd still photos of an object from a variety of directions, then upload them all to the Autodesk server, which after a few minutes will return a 3D model. Inevitably, it's somewhat hit-and-miss, and the results can require a lot of cleaning up in software. *[continued on p78]*



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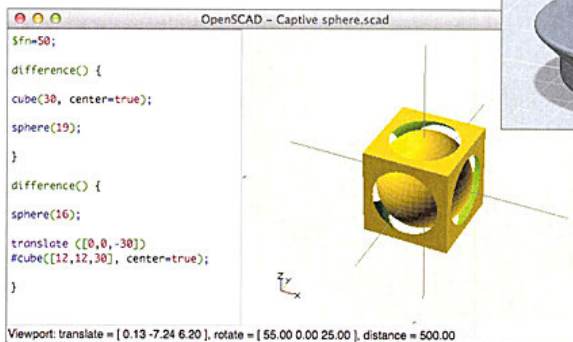
Creating a model



Autodesk's free CAD program, 123D Design, lets you create models using Bézier curves or primitive shapes. Parts snap to each other and can then be smoothed using filleting tools.



The printed object. After all, why shouldn't a bath plug be a thing of beauty?



We drew this captive sphere in the free text-based CAD app OpenSCAD using just 10 lines of code, then printed it. Try making this any other way!



[continued from p77] If you have access to Photoshop CC (£8.78 per month from adobe.com/uk), you can design your own 3D objects directly in the app. The tools are limited, but it's a good solution for tasks like creating 3D versions of company logos.

Another free Autodesk app, 123D Design, is a 3D printing-oriented CAD package that allows you to build complex and precise models with relative ease. It has a slightly quirky interface, but it's powerful enough to make almost any straightforward model.

The web app Tinkercad, free to use at tinkercad.com, is easy to learn, providing basic tools for building 3D objects which you can then download to your Mac. Previously a paid-for service, it's now owned by Autodesk.

For a more rigorous approach, the free program OpenSCAD is a non-visual design environment in

which you type the sizes, locations and orientation of your desired model elements, while seeing a live preview of the end result. It's as tricky to learn as it sounds, but very powerful, and the text entry approach makes it easy to customise and modify your results.

Print prep Once you have a finished 3D model, you'll need to make it print-ready. Most printable 3D files are supplied in the STL (short for 'stereolithography') file format, which is a universal interchange format aimed at printing. 3D printers, however, require models to be in GCode format, which adds the specifications for the thickness of each printed layer, print temperature and speed, the fill density and so on.

Photoshop CC can import models in a variety of formats, then print them directly to the small range of

printers it supports. If yours isn't one of those on the list, you can build your own export code, although this requires a good degree of technical knowledge. The best thing about the Photoshop solution is its ability to import models from any source and make them 'watertight' for output.

To create your own GCode files, you'll need an app such as Ultimaker's Cura (software.ultimaker.com), which allows you to specify all the printing parameters and includes a 'quick' mode for the less technically inclined. Many printers, including MakerBot's, come with their own apps for converting and printing 3D objects.

Is 3D printing really ready for the mass market? It's tantalisingly close, but look at it this way: there's still time to get a head start. In another year, it could be you welcoming the rest of us into your world.