

# 3D-Printable Micropipette

Martin D. Brennan<sup>1</sup>, Fahad F. Bokhari<sup>1</sup>, David T. Eddington<sup>1,\*</sup>,

**1 Department of Bioengineering, University of Illinois at Chicago, Chicago, Illinois, USA**

\* [dte@uic.edu](mailto:dte@uic.edu)

## Abstract

Open source development of lab equipment is being facilitated, in part, by growing availability of 3D printing which allows the production of simple lab tools. We developed 3D-printable parts that, along with a disposable syringe, form a micropipette. Once assembled the pipette requires no calibration or validation with a scale. Our printed micropipette is assessed in comparison to a commercial pipette demonstrating comparable performance in accuracy and precision and approaches ISO standard.

## Introduction

The open source development model, initially applied to software, is thriving in the development of open source scientific equipment due in part to increasing access of 3D printing [1,2]. Additive manufacturing methods have existed for decades although the recent availability of inexpensive desktop printers [?,3] have made it feasible for consumers to design and print prototypes and even functional parts, and consumer goods [4]. Proliferation of free CAD software[OpenSCAD, Blender, SketchUp] and design sharing sites [?,3,5,6] have also supported the growth and popularity of open designed parts and projects. Open design 3D-printable lab equipment is an attractive idea because, like open source software, it allows free access to technology that is otherwise inaccessible due to proprietary and/or financial barriers. Open design tools create opportunity for scientists and educational programs in remote or resource limited areas to participate with inexpensive and easy to make tools [1]. Open source development also enables the development of custom solutions to meet unique applications not met by commercial products that are shared freely and are user modifiable [4,7]. Some advanced, noteworthy, open-source scientific equipment include a PCR device [8], and a two-photon microscope [9] although simple tools are often more impactful as they can serve a wider community. Some simple and clever printable parts that have emerged are ones that give a new function to a ubiquitous existing device, such as drill bit attachment designed to hold centrifuge tubes, allowing a drill to be used as a centrifuge [10]. Although this may make a rather crude centrifuge it may be an adequate method which only costs pennies compared to commercially available centrifuges. Other examples of open-design research tools that utilize 3D printed parts include optics equipment [11], microscopes [12,13], syringe pumps [14], and reactionware [15] to name a few.

One example of a everyday scientific tool that provides opportunity for an open design solution is the micropipette. Micropipettes are an indispensable tool used routinely in lab tasks and can easily cost \$1000 USD for a set. Often a lab will require

several sets each for a dedicated task. Some pipettes are even re-calibrated for use with liquids of different properties. A open design pipette that can be made for cheap can cut costs for labs as well as allow a option for educational settings.

Air displacement pipettes use a piston operating principal to draw liquid into the pipette [?]. In a typical commercial pipette the piston is made to be gas-tight with a gasketed plunger inside a smooth barrel. Consumer grade fused deposition modeling (FDM) printers are unable to build a smooth surface do to the formation of ridges that occur as each layer is deposited. The ridges formed by FDM make it impractical to form a gas-tight seal between moving parts, even with a gasket. Existing printable open-design micropipettes get around this limitation by stretching a membrane over one end of a printed tube, which when pressed causes the displacement. The displacement membrane can be made from any elastic material such as a latex glove. There are a few open design printable micropipettes including a popular one which, in addition to the printed parts, uses parts scavenged from a retractable pen [16]. Because there is no built-in feature such as a readout for the user to set the displacement to a desired volume, this design requires the user to validate the volumes dispensed with a high precision scale. Without verification with a scale the volumes dispensed can only be estimated based on calculations of the deflection of the membrane.

We submit a new design whose major strength is the ability to adjust to any volume according to built in scale. Our open design 3D-printable micropipette works by actuating a disposable syringe to a user adjustable set-point. This allows the user to set the pipette to a volume by reading the graduations on the syringe barrel. The scale marks on the syringe can be used to adjust the dispensed volume accurately without calibrating with a scale. Our pipette also offers a simplified assembly requiring no glue, tape or permanent connections.

## Methods

Our printed pipette is designed to actuate a 1 mL or 3 mL syringe to a user set displacement. The core of the design is two printed parts, the body and the plunger which are able to be printed on a consumer grade FDM printer. A 1 mL or 3 mL syringe twists to lock in the body part and is held into place by the syringe flanges. The 30-300 uL configuration uses a 1 mL pipette and the 100-1000 uL configuration uses a 3 mL pipette. The plunger part slides freely in the body part and actuates the syringe by pushing the thumb press. The pipette is spring loaded towards a set point which is adjustable by a set-screw. When the plunger is depressed the system locks when it reaches the latched position, where it is ready to draw in fluid. The plunger is held in place with a latching button design which is released with a lever drawing in fluid. The displacement is equal to the distance between the set position and the latched position. The pipette can also be pressed past the latched position to 'blow-out' the transferred fluid completely from the pipette tip. Additional materials required for assembly include a spring, a nut and bolt and washers. Attempts to make a printable luer lock adapter for tips was abandoned as the surface of printed parts is too rough to make an air tight seal with the luer or pipette tip. Instead a combination of a barbed luer adapter and elastic tubing is used to attach the pipette tips. Our printed pipette mimics commercial pipettes design, function, and user operation, making it intuitive to use. Conveniently this design can also reach to the bottom of a 15 mL conical tube allowing tasks such as aspirating supernatant fluid from a cell pellet.

Our pipette uses the air-displacement design, where a pocket of air is used to draw liquid into the pipette. As air is an compressible fluid, this pocket of air grows due to the weight of the liquid pulling on it. Due to this effect the graduations on the syringe are not accurate, as they are designed for measuring liquid within the syringe. At larger

**Figure 1. CAD renderings of printable parts.** Two parts are printed: The plunger part (A) slides inside the body part (B).

volumes this effect is more pronounced resulting in the volume measured being greater than the amount of liquid pulled into the syringe. We remedied this by creating a new scale to account for the expansion. The scale is printed on a transparency sheet and is pasted on the syringe for accurate measurements.

## Assembly

A small amount of paraffin wax is applied to the screw to prevent slop from causing the set point to drift after each actuation. The nut is sunk in to the hex inset in the body part. The bolt is threaded in from the top of the body into the nut. Springs and washers are threaded onto the plunger of the 1 mL syringe for the 30-300 uL configuration. Springs are placed inside the 3 mL syringe for the 100-1000 mL configuration. The plunger part is inserted in the body and the syringe assembly is pushed in and locked from the syringe flanges to the body part to complete assembly. Parts and cost are listed in tables ??

**Table 1.** Parts and cost for the 30-300 uL pipette.

| Part         | Unit Price | Source         | Part number |
|--------------|------------|----------------|-------------|
| Filament     | \$1.63     | Makerbot       | NA          |
| 1 mL Syringe | \$0.15     | BD Biosciences | 309628      |
| Bolt         | \$0.12     | McMaster-Carr  | 91287A026   |
| Nut          | \$0.01     | McMaster-Carr  | 90591A121   |
| Spring (2)   | \$4.14     | McMaster-Carr  | 94125K542   |
| Washers (2)  | \$0.16     | McMaster-Carr  | 90107A012   |
| total        | \$6.21     |                |             |

**Table 2.** Parts and cost for the 100-1000 uL pipette.

| Part         | Unit Price | Source         | Part number |
|--------------|------------|----------------|-------------|
| Filament     | \$1.63     | Makerbot       | NA          |
| 3 mL Syringe | \$0.73     | BD Biosciences | 309657      |
| Bolt         | \$0.12     | McMaster-Carr  | 91287A026   |
| Nut          | \$0.01     | McMaster-Carr  | 90591A121   |
| Spring (2)   | \$4.14     | McMaster-Carr  | 94125K542   |
| total        | \$6.63     |                |             |

## Validation

The printed pipette's accuracy and precision was characterized and compared to a commercial pipette as well as ISO 8655. The printed pipette was adjusted to the target volume by eye from the syringe graduations, and the resulting volume was measured and repeated 5 times to account for transfer variability. Data was taken for printed pipettes with existing syringe graduations as well as with the our adjusted scale. Data was taken with commercial pipettes of 30-300 and 100-1000 to compare to the printed pipette. The systematic error and random error was calculated according to ISO 8655 ?? (Table ??).

**Figure 2. CAD renderings of assembled pipette and function.** The pipette actuates the syringe to three positions. (i) **The set position.** The position of the screw determines the total displacement. The pipette is spring loaded to return to this position (ii) **The latched position.** When the plunger is pressed the pipette locks at this position. The tip is then placed in a liquid and the button pressed to release the pipette back to the set position, drawing in liquid. (iii) **The blow-out position.** The fluid is transferred by pressing the plunger past the latched position to blow-out all the liquid.

**Figure 3. Photos of pipette.** The pipette is composed of two printed parts, a 1 mL syringe and some additional hardware.

## Results and Discussion

Validation testing performed with the existing graduations printed on the syringes did not meet the ISO standards. Due to the expansion of air the built in graduations were not accurate, especially at larger volumes. Replacing the scale with our scale that accounts for the expansion corrected this effect. Our printed pipette with the adjusted scale meets ISO standards for accuracy and precision. (Table ??).

Our printed pipette improves on existing open design pipettes in several ways. Most significantly the user is able to adjust the syringe accurately without verifying the volume with a scale. In addition the assembly requires no permanent connections using tape or glue which allows for re-configuration and easy replacement of parts. Our pipette is able to transfer from the bottom of a 15 mL conical tube which is a requirement for many routine lab procedures such as aspirating supernatant from a centrifuged cell pellet. This design does not use a membrane that may wear out and require tedious replacement.

The only major limitation of this design compared to the biopipette is the option for a pipette tip ejector. The biopipette also uses easier to source parts relative to what is required from our design.

For more information, see ??.

## Supporting Information

## References

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**Table 3.** ISO 8655 for 100-1000 uL comparing a commercial pipette with our printed pipette used with existing 3 mL syringe scale and an adjusted scale

|         |                       | Mean    | Systematic Error | % Sys. err. | Random Error | % Rand. err. |
|---------|-----------------------|---------|------------------|-------------|--------------|--------------|
| 1000 uL | ISO 8655, 100-1000 uL | 1000    | 8.00             | 0.80        | 3.00         | 0.30         |
|         | Commercial Pipette    | 1002.98 | 2.98             | 0.30        | 1.72         | 0.17         |
|         | Printed Pipette       | 949.29  | -50.71           | -5.07       | 0.60         | 0.06         |
|         | Printed Pipette Scale | 1003.57 | 3.57             | 0.36        | 0.89         | 0.09         |
| 500 uL  | ISO 8655, 100-1000 uL | 500     | 8.00             | 1.60        | 3.00         | 0.60         |
|         | Commercial Pipette    | 503.67  | 3.67             | 0.73        | 0.49         | 0.10         |
|         | Printed Pipette       | 475.99  | -24.01           | -4.80       | 4.75         | 1.00         |
|         | Printed Pipette Scale | 503.62  | 3.62             | 0.72        | 1.64         | 0.33         |
| 200 uL  | ISO 8655, 100-1000 uL | 200     | 8.00             | 4.00        | 3.00         | 1.50         |
|         | Commercial Pipette    | 204.61  | 4.61             | 2.30        | 0.15         | 0.07         |
|         | Printed Pipette       | 186.55  | -13.45           | -6.72       | 1.31         | 0.70         |
|         | Printed Pipette Scale | 201.87  | 1.87             | 0.94        | 1.47         | 0.73         |
| 100 uL  | ISO 8655, 100-1000 uL | 100     | 8.00             | 8.00        | 3.00         | 3.00         |
|         | Commercial Pipette    | 104.29  | 4.29             | 4.29        | 1.65         | 1.58         |
|         | Printed Pipette       | 94.02   | -5.98            | -5.98       | 4.81         | 5.12         |
|         | Printed Pipette Scale | 101.00  | 1.00             | 1.00        | 1.05         | 1.04         |

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**Table 4.** ISO 8655 for 30-300 uL comparing a commercial pipette with our printed pipette used with existing 3 mL syringe scale and an adjusted scale

|        |                       | Mean   | Systematic Error | % Sys. err. | Random Error | % Rand. err. |
|--------|-----------------------|--------|------------------|-------------|--------------|--------------|
| 300 uL | ISO 8655, 30-300 uL   | 300    | 4.00             | 1.33        | 1.50         | 0.50         |
|        | Commercial Pipette    | 301.19 | 1.19             | 0.40        | 0.53         | 0.18         |
|        | Printed Pipette       | 286.91 | -13.09           | -4.36       | 0.42         | 0.15         |
|        | Printed Pipette Scale | 299.11 | -0.89            | -0.30       | 0.48         | 0.16         |
| 200 uL | ISO 8655, 30-300 uL   | 200    | 4                | 2           | 1.5          | 0.75         |
|        | Commercial Pipette    | 200.06 | 0.06             | 0.03        | 0.46         | 0.23         |
|        | Printed Pipette       | 193.40 | -6.60            | -3.30       | 2.86         | 1.48         |
|        | Printed Pipette Scale | 200.57 | 0.57             | 0.28        | 0.86         | 0.43         |
| 50 uL  | ISO 8655, 30-300 uL   | 50     | 4                | 8           | 1.5          | 3            |
|        | Commercial Pipette    | 49.02  | -0.98            | -1.96       | 0.10         | 0.20         |
|        | Printed Pipette       | 49.62  | -0.38            | -0.76       | 1.26         | 2.53         |
|        | Printed Pipette Scale | 48.73  | -1.27            | -2.54       | 1.11         | 2.27         |
| 30 uL  | ISO 8655, 30-300 uL   | 30     | 4                | 13.3        | 1.5          | 5            |
|        | Commercial Pipette    | 29.08  | -0.92            | -3.06       | 0.09         | 0.31         |
|        | Printed Pipette       | 29.22  | -0.78            | -2.59       | 0.31         | 1.07         |
|        | Printed Pipette Scale | 27.78  | -2.22            | -7.41       | 1.37         | 4.93         |
| 20 uL* | ISO 8655, 30-300 uL   | 20     | 4                | 20          | 1.5          | 7.5          |
|        | Commercial Pipette    | NA     | NA               | NA          | NA           | NA           |
|        | Printed Pipette       | 18.70  | -1.30            | -6.48       | 0.38         | 2.01         |
|        | Printed Pipette Scale | 17.94  | -2.06            | -10.29      | 1.87         | 10.42        |
| 10 uL* | ISO 8655, 30-300 uL   | 10     | 4                | 40          | 1.5          | 15           |
|        | Commercial Pipette    | NA     | NA               | NA          | NA           | NA           |
|        | Printed Pipette       | 11.95  | 1.95             | 19.52       | 0.73         | 6.08         |
|        | Printed Pipette Scale | 7.64   | -2.36            | -23.64      | 0.38         | 4.92         |

\* The 20 uL and 10 uL volumes are out of the range in this case but we wanted to demonstrate that the pipette is capable of even smaller volumes.

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