The ability to generate and collect large amounts of data quickly and reliably remains a persistent hurdle - we are just in the early stages of using modern technology and global accessibility as research tools to overcome it.

Here, I present a website framework that is accessible and adaptable for a variety of data collection projects and test the precision and accuracy of web-based tools for use in research.

Web-based tools provide an effective alternative to traditional methods for making specimen measurements

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Benefits of using web-based tools

» Improved accuracy
Measurements can be constrained to paths and areas dictated during website development. Input values are stored automatically, removing user input error.

» Increased transparency and reproducibility
Detailed data (absolutely positions, angles) and metadata (timestamp, browser) can be stored alongside primary data for future inspection.

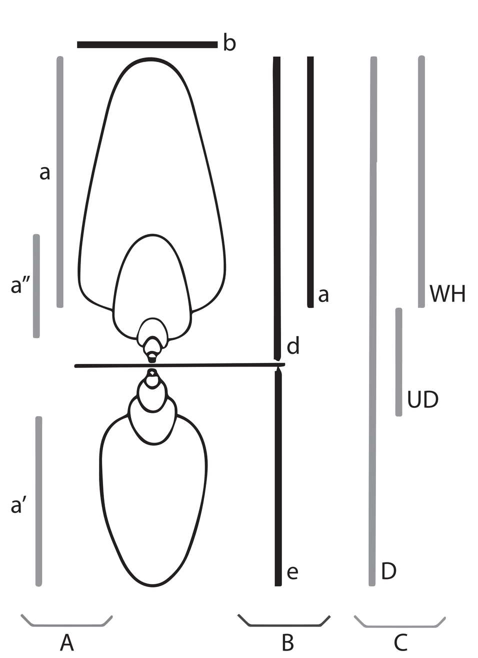
» Streamlined workflow
Auto-step advancement and data recording reduces the amount of time spent making measurements. (One full set of measurements for this study can be completed in 30 seconds using the website.)

» Broad accessibility
Many people can work simultaneously on data collection from different locations.

But is it as precise and accurate as traditional methods?
Does a lack of access to formal training compromise results?

Methods

Three methods were used to collect linear measurements of ammonite shells:
1) **manually** from specimens using digital calipers
2) using a custom-built **website** with front and side view photographs
3) using **ImageJ**, a widely used program for collecting counts and measurements, with front and side view photographs.



For five specimens, I measured lengths *D*, *d*, *a*, *UD*, and *b* (Fig. 1). In addition to data collected by the author, student volunteers were asked to collect the same measurements using the three methods, following initial data collection via the website without any prior instruction or specimen handling ("**pre-training**").

The measurements were then used to generate three parameters historically used to charterize ammonite shell coiling: *U* (U=UD/D), *S* (S=a/a'), and *w* (w=b/a).

Figure 1. Diagramatic cross-section of an ammonite shell and commonly used measurements. (Ritterbush and Bottjer 2012)

Comparing accuracy and precision

For five ammonite specimens, I compared coiling parameter values calculated using each of the three methods.

Accuracy: No significant difference was found in mean parameter values between the three methods across all specimens (Fig. 1, *p*-value = 0.603, repeated measures ANOVA). **Website measurements were as accurate as measurements obtained via other methods.**

Precision: Mean standard errors obtained using each method do not differ from each other (Fig. 3, *p*-value = 0.122, repeated measures ANOVA). **Website measurement were as precise as measurements obtained via other methods.**

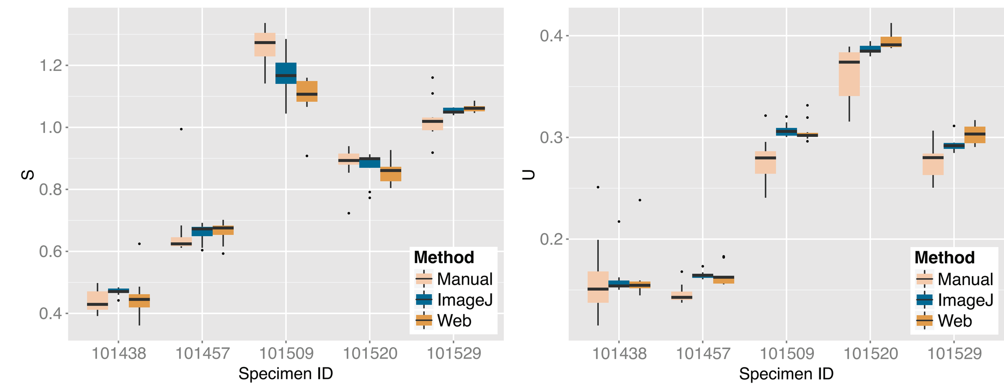
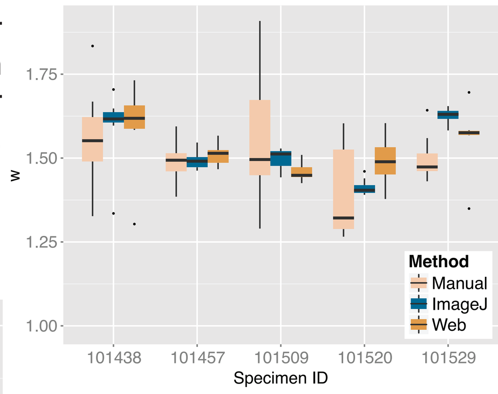


Figure 2. Growth parameter values obtained using each method. Boxes indicate inner quartile ranges.



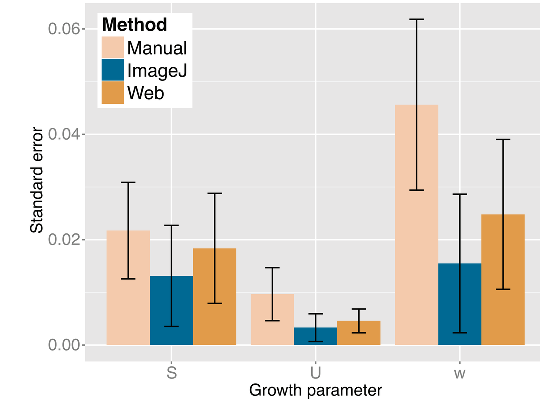


Figure 3. Mean standard errors of growth parameter values obtained using each method. Standard deviations shown.

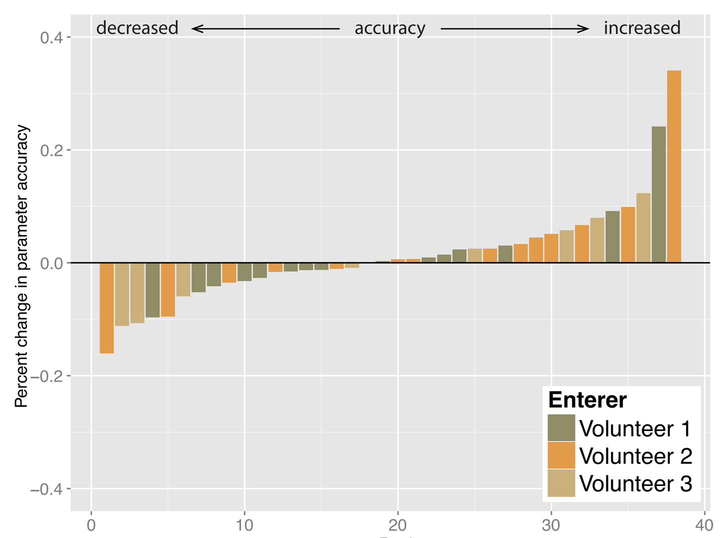


Figure 4. Percent improvement in accuracy of parameters taken via the website after receiving instructions for manual measurements. Comparison of accuracy is made against the mean of manual measurements for that parameter per specimen.

Effect of training

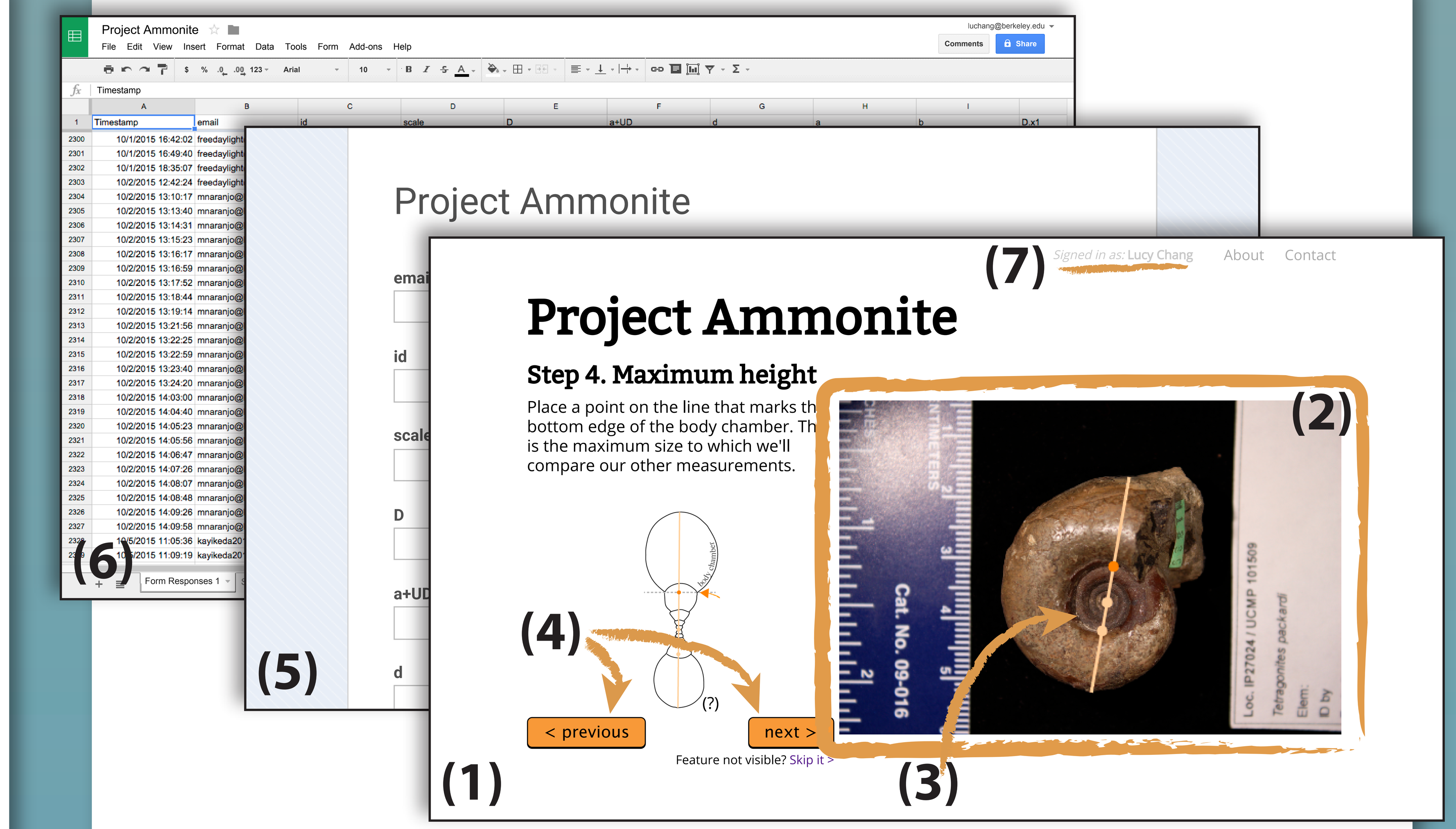
I compared measurements taken via the website by volunteers with no prior knowledge to those taken after the volunteer received training measuring the specimens manually.

Average improvement in accuracy after having received training was indistinguishable from 0 (*p*-value = 0.6775, Wilcoxon signed-rank test). While there was improvement in some measurements, no one volunteer showed consistent improvement (Fig. 4).

Training improved measurement accuracy in some cases, but the effect was inconsistent and small. *Thus, untrained volunteers mobilized by* ***crowdsourcing efforts*** *may be a valuable resource for accelerating data capture.*

Web-based measurements were as precise and accurate as other widely used methods.

There was no evidence that training significantly improved measurement accuracy.



Website components

The website used in this study was built using **(1, see above) HTML5**. This takes advantage of the **(2) <canvas>** element, which allows dynamic and interactive imagery to be generated instantaneously.

The user interacts with <canvas> via **(3) Fabris.js**, a freely available Javascript library. This library is responsible for the points and lines drawn in <canvas>. In order to render these objects, mouse click positions in <canvas> are stored. We use the stored positions to calculate the desired measurements.

With additional basic **(4) Javascript**, the measurements are fed directly into hidden **(5) Google Form** input boxes, which upon submission after the final measurement, creates a record in **(6) Google Sheets**. **(7) Google Sign-In** (optional) provides unique identifiers (in this case, email addresses) for each submission.

Because of programming of steps in the data collection process is modular, this framework is highly adaptable to other applications.

VISIT: www.ocf.berkeley.edu/~luchang/ammonite/

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