Soil Texture Estimates: A Tool to Compare Texture-by-Feel and Lab Data

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ABSTRACT Soil texture is a fundamental soil property that impacts agricultural and engineering land-use. Comparing texture estimates-by-feel to laboratory-known values to calibrate fingers is a common practice. As educators, it is difficult to assess this field skill consistently and fairly. The instructor may give full credit for the correct texture class and partial credit for adjoining classes. This works well if the sample is near the center of a class, but not so well if it is near a class boundary. This article describes a computer program methodology using simple trigonometric principles to accurately assess student performance for estimating particle-size distribution (PSD) and soil textural classes. The concept is to plot the estimated PSD and the actual PSD on a texture triangle, calculate the distance between the two points using the scale along any side of the triangle (100 units), and subtract that distance from 100 to obtain a score. If the estimate coincides exactly with laboratory results, the score is 100%. If the estimate and laboratory results are as far apart as possible, at opposite corners of the texture triangle, the score is zero. Other scores are based on the distance between points representing the estimate and the actual on a texture triangle in relation to the length of one side of the triangle. The texture estimator provides a quantitative, consistent, and easy-to-use method of assessing students' performance. Additionally, this program allows students to observe the errors in estimates, which provides a further educational benefit.

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Soil texture is a fundamental soil property that impacts both agricultural and engineering land-use. The laboratory procedure used to determine the fractions of sand, silt, and clay is costly and time consuming; therefore, methods have been developed to estimate soil texture by sensory observations, primarily with tactile manipulation with fingers, of a moist soil sample (Thein, 1979). Many times students and practitioners have honed their skills by developing unique individually specific techniques (e.g., the shine test for clay) and can consistently get within a few percent of laboratory analyses. This skill can only be accomplished by comparing estimates based on laboratory "known" values and practice. In several states such as Indiana and Michigan (Johnston, 2005), student clubs sell soil texture kits with particle-size laboratory data. These kits can be used by agri-science teachers to teach high school students to texture soils and by professionals to "calibrate" their fingers to accurately determine soil textures by the feel method.

Texture-by-feel is used for many scientific purposes. Sometimes field texture estimates are used in scientific field studies where many texture samples are needed to determine differences among soils (Rahman et al., 1996). Field textures or apparent field textures are mentioned in the *Soil Survey Manual* (Soil Survey Staff, 1993) as tactile evaluations only with no reference to laboratory test results. However, these texture-by-feel evaluations are used as primary data when assigning soil series mapping units for soil surveys. Onsite wastewater filter fields (septic system filter fields) are sized based on field estimates of texture. In Indiana, if a soil scientist estimated a texture of silt loam, the loading rate would be 2.0 cm day^{-1} (0.50 gallons ft^{-2} day^{-1}), costing the homeowner about $6000 for the septic system; however, a texture of clay loam would give a loading rate of 1.2 cm day^{-1} (0.30 gallons ft^{-2} day^{-1}), costing the homeowner about $9000 (ISDH, 1990). The consequences of undersizing a system could lead to septic system failure, which would cause health hazards, fines, and even property condemnation. Because many field evaluations require texture estimates, which impact society, texture assessment is conducted in some states for professional registry. For example, Indiana Registered Soil Scientists are required to estimate unknown soil textures at least once every 3 years to be eligible to renew their registration.

Impact Statement

In most states, soil scientists use texture-by-feel to assign loading rates for septic system filter fields. Missing the clay percentage and under-sizing a septic system filter field can cause sewage to surface and create a health hazard for a homeowner. Methods to estimate texture are individually developed and require practice comparing estimates with known sand, silt, and clay from laboratory data. This tool provides instructors with a consistent, reliable method of evaluating soil texture estimates.

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Abbreviations: PSD, particle-size distribution.

Table 1. Particle-size data and calculated values for Soil Sample 1.

Description	Symbol	Sand	Silt	Clay
		Particle-size separate		
		—%		
Given values				
Estimated PSD (clay loam texture class)	E	25	45	30
Laboratory PSD (clay texture class)	A	16	22	62
Calculated values				
Difference (E – A)		9	23	–32
Line AB (= BC = AC); absolute values	AB	32	32	32
Corner of triangle	B	16	54	30
Corner of triangle	C	48	22	30
Midpoint of line BC	D	32	38	30
Line DE (SD – SE)		7		

Since this the texture-by-feel method is a fundamental skill needed by soil scientists, one of the essential objectives in introductory soils classes is teaching this method. In advanced field classes such as Collegiate Soils Evaluation Contests, students are required to estimate sand, silt, and clay (within 5%) and determine the correct texture class; whereas beginning courses may require students to identify soil texture classes rather than actual percentages. In both cases, students are asked to estimate the texture of samples on which particle-size distribution (PSD) has been determined in the laboratory. Thein (1979) published a flow chart that provides students a baseline to assign texture classes; however, assessment of performance of hand texturing, especially at advanced and professional levels, is difficult. At both the student and the professional level, the goal is to evaluate the PSD estimates objectively—that is, to assign the participant a grade that reflects the learned skill. The instructor might give full credit for getting the correct texture class and allow partial credit for contiguous classes on the texture triangle. This is fair if the data place the sample near the center of a class. What happens, however, if the sample plots near a class boundary? One student's estimate of PSD could be very near the lab values, but just across a class boundary and it would earn half credit. Another student's estimate could be in the same class, but far from the lab results and that student would earn full credit. An evenly applied assessment is necessary; therefore, our goal for this project was to develop a method of evaluating texture estimates that is quantitative, robust, fair, and user friendly.

Method

The idea behind this method is to use simple trigonometry principles to accurately assess student's performance for estimating soil particle-size distribution and soil textural classes. The concept is to plot the estimated particle size distribution and the actual PSD on a texture triangle, calculate the distance between the two points using the scale along any side of the triangle (100 units), and subtract that distance from 100 to obtain a score. Accordingly, if the two points coincide, the score is 100%; if they are at opposite corners of the triangle (e.g., 100% clay vs. 100% sand), the score is zero. Between these extremes, the closer the two points, the higher the score.

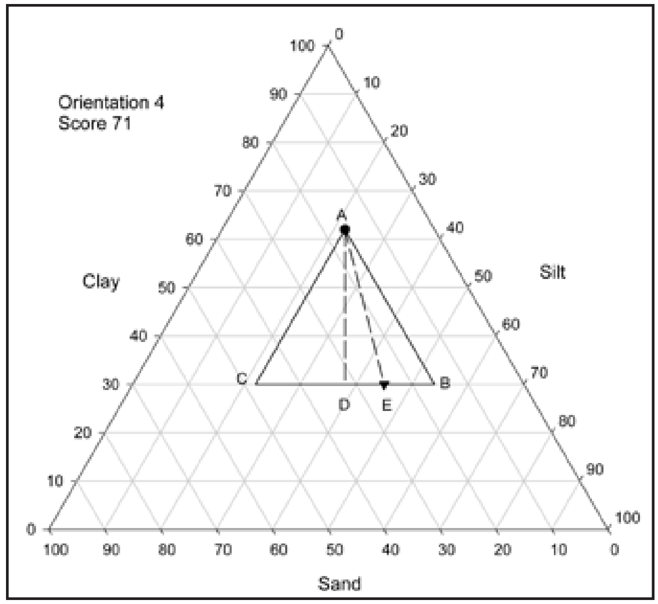

Fig. 1. Graph illustrating calculation of the distance between points representing the laboratory (Point A) and estimated (Point E) particle-size distributions for Soil Sample 1.

The general details of this method are explained here for a specific example described in Table 1 and Fig. 1. First, the lab PSD (circle symbol, A) is plotted and the student estimated PSD (triangle symbol, E) on the texture triangle, and then draw an equilateral triangle (ABC) creating a texture estimator triangle. The texture estimator triangle contains these characteristics:

- The sides are parallel to those of the USDA texture triangle.
- Point A is at one corner of the triangle and the opposite side goes through point E.
- The other corners are labeled B and C clockwise around the triangle.
- Point D bisects line BC.

Thus, the farther apart the two PSD values, the larger the texture estimator triangle.

To determine the difference between lab and estimated textures, the length of line AE in the texture estimator triangle must be calculated. This can be done if AD and DE are known. The length of AD is calculated from the length of line AB. The length of any side of triangle ABC, including AB, is equal to the maximum difference between any particle-size separate (sand, silt, or clay). In this case, the differences (estimated – lab) are sand, 9%; silt, 23%; clay, –32%, so the sides of the small triangle are 32 units (%) long. DE is calculated from the laboratory sand content as

Table 2. Particle-size data and calculated values for Soil Sample 2.

Description	Symbol	Sand	Silt	Clay
		Particle-size separate		
		%		
Given values				
Estimated PSD (sandy loam texture class)	E	80	15	5
Laboratory PSD (loamy sand texture class)	A	62	22	16
Calculated values				
Difference (E – A)		18	−7	−11
Line AB (= BC = AC); absolute value	AB	18	18	18
Corner of triangle	B	80	22	−2
Corner of triangle	C	80	4	16
Midpoint of line BC	D		13	
Line DE (SID – SIE)			−2	

shown below for example 1 in which line BC follows a uniform clay percentage line and is parallel to the sand axis. As discussed later, other orientations are possible.

Example 1

$$AB = \text{length of line AB } (= BC = AC) \qquad [1]$$

$$= \text{maximum difference in clay} = 32$$

$$AD = \sin 60^{o} \times AC \qquad [2]$$

$$= 0.866 \times 32 = 27.7$$

$$DE = S_D - S_E \ (S_D = \text{sand content at point D}, S_E = \text{sand content at point E})$$

$$S_D = S_B + AB/2 \ (S_B = S_A = S_{lab} = 16)$$

$$S_E = S_{est} = 25 \ (S_{est} = \text{estimated estimate of sand content})$$

$$DE = (S_{lab} + AB/2) - S_{est} \qquad [3]$$

$$= (16 + 16) - 25 = 7$$

$$AE = \text{square root } (AD^2 + DE^2) \qquad [4]$$

$$= \text{square root } (27.7^2 + 7^2) = 28.6$$

$$\text{Score} = 100 - AE = 71.4$$

For example 2 (Table 2 and Fig. 2), the orientation of the small triangle is different.

Example 2

$$AB = 18 \text{ (maximum difference in sand content)} \qquad [5]$$

$$AD = \sin 60^{o} \times AC \qquad [6]$$

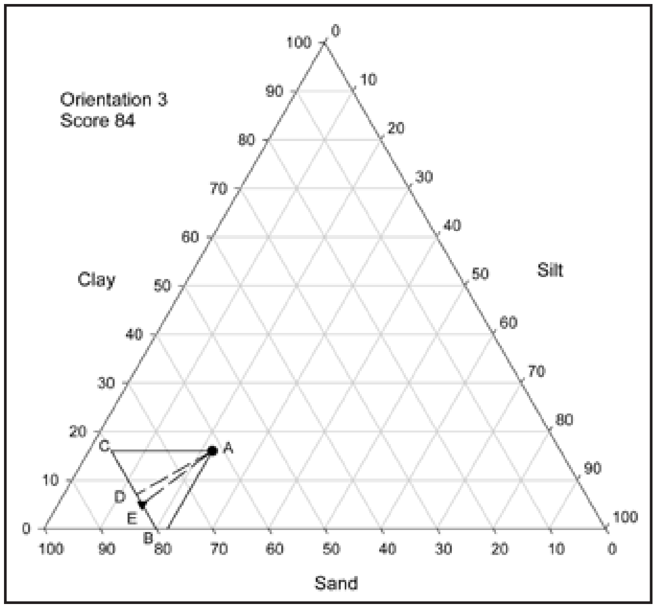

Fig. 2. Graph illustrating calculation of the distance between points representing the laboratory (Point A) and estimated (Point E) particle-size distributions for Soil Sample 2.

$$= 0.866 \text{ x } 18 = 15.6$$

$$DE = (SI_{lab} - AB/2) - SI_{est} \qquad [7]$$

$$= (22 - 9) - 15 = -2$$

$$AE = \text{square root } (AD^2 + DE^2) \qquad [8]$$

$$= 15.7$$

$$\text{Score} = 100 - AE = 84.3$$

Notice that Eq. [2] and [6] are the same for both examples, as are Eq. [4] and [8]; however, Eq. [3] and [7] differ. Equation [3] includes percentage of sand, and Eq. [7] includes percentage of silt, and the sign of the term BC/2 differs. Also, part of triangle ABC can be outside the texture triangle, as shown in Fig. 2. The two triangles are oriented differently.

In this arrangement, there are six possible relationships, or orientations, of estimated and actual PSD. They are represented mathematically in Table 3 and graphically in Fig. 3. In practice, the orientation is determined before the calculations illustrated by the above equations are applied. Samples 1 and 2 have orientations 4 and 3, respectively. Knowing the orientation for a specific sample is useful to the participants because it lets them know if their major error is to overestimate or underestimate sand, silt, or clay, the six possibilities listed in Table 3. If, for example, students estimate PSD on a number of samples and have the same major error on most of them, they can make the necessary adjustment in subsequent work.

Table 3. Orientation of the small triangle ABC.

Difference (estimated – lab)			Orientation (ORN)	Equation for DE	Major error
S	SI	C			
<0	<0	≥0	1	Slab – AB/2 – Sest	overestimate clay
<0	≥0	<0	2	Clab – AB/2 – Cest	overestimate silt
≥0	<0	<0	3	SIlab – AB/2 – SIest	overestimate sand
≥0	≥0	<0	4	Slab + AB/2 – Sest	underestimate clay
≥0	<0	≥0	5	Clab + AB/2 – Cest	underestimate silt
<0	≥0	≥0	6	SIlab + AB/2 – SIest	underestimate sand

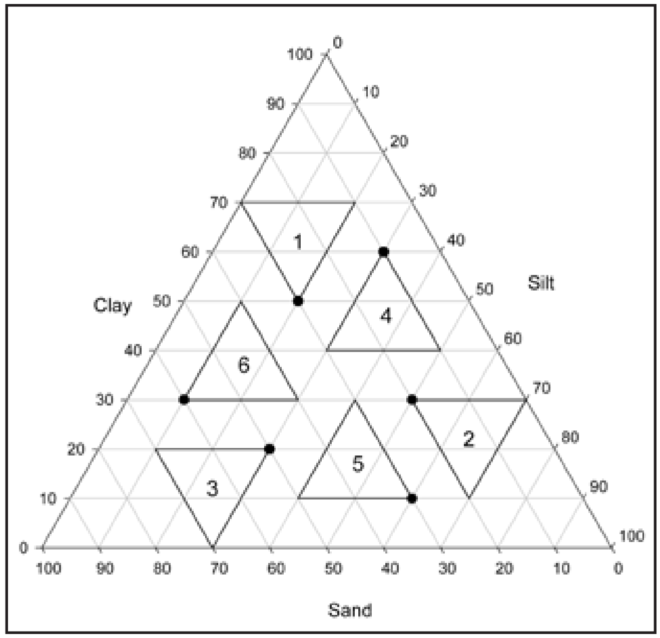

Fig. 3. Graph showing the six orientations of triangles such as those in Fig. 1 and 2. The filled circles represent Point A of Fig. 1 and 2. Point E may be anywhere along the line opposite of Point A.

Application

The calculations presented here were performed using Microsoft Excel spreadsheet using mathematical and conditional formulas. Table 4 shows the structure of the table and the formulas. Calculations are shown for the two examples discussed previously. Sample identification is entered in column A. Actual (lab) and student-estimated sand and clay percentages are entered in columns B through E. Entries in all other columns are calculated by formulas, which are simple subtractions in columns F through J. The formula in column K determines the orientation as described in Table 3 and Fig. 3. Formulas for columns L through O are derived from the equations given earlier.

A simplified MS Excel spreadsheet has been posted on Resources link on the Indiana Registry of Soil Scientists website: http://www.isco.purdue.edu/irss/index.html (verified 5 Sept. 2008). The spreadsheet has two rows that illustrate the example calculations as described in Table 3 and additional rows below for users to enter data to obtain scores. To use this section of the spreadsheet enter a student name or ID, the student's estimate, and laboratory data for clay and sand. The scores will automatically appear in the column on the right under "Score." The spreadsheet is set so that the scores may be printed on an 8.5 by 11 inch sheet of paper.

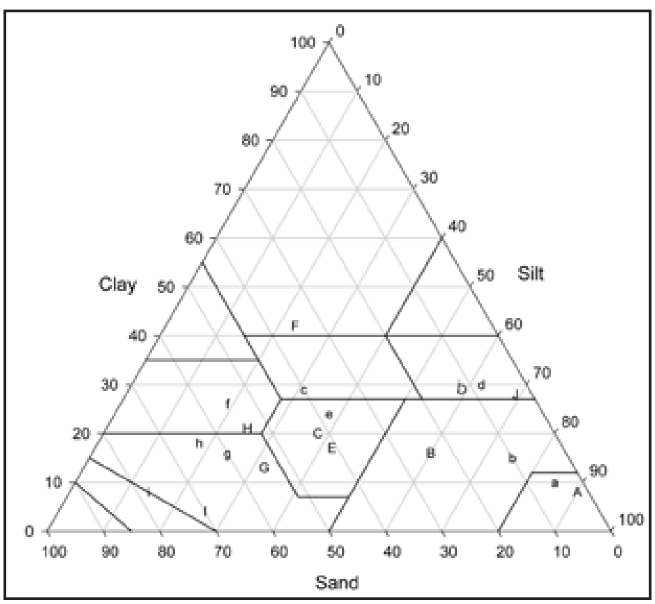

Fig. 4. Comparison of estimated (lower case) and laboratory (upper case) particle-size distributions for 10 soil samples.

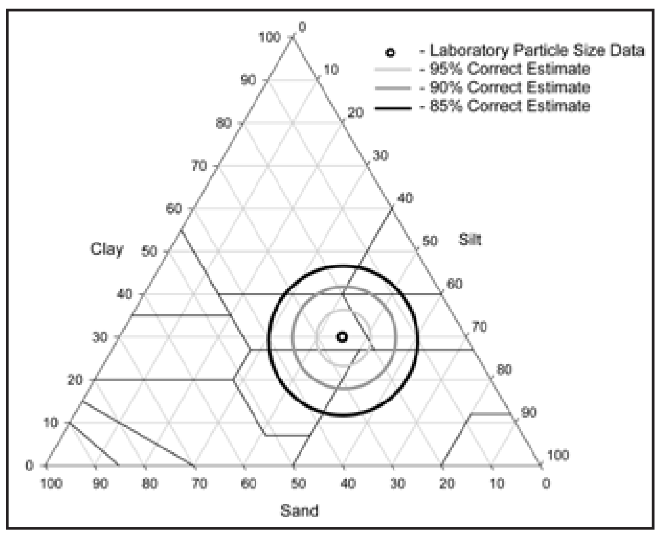

Fig. 5. Textural triangle illustrating a laboratory result (circle) and the range of scores of 95, 90, and 85%.

Table 4. Example of MS Excel table. Data are entered in columns A–E. Numbers in columns F–J were calculated by subtraction formulas. Formulas for columns K–P are given below the table for line 4. Data in lines 3 and 4 are for from Tables 1 and 2 and Fig. 1 and 2.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	ID	Student		Lab		St	Lb	Student − Lab			ORN	AB	AD	DE	AE	SCORE
2		S	C	S	C	Si	Si	S	Si	C						
3	1	25	30	16	62	45	22	9	23	−32	4	32	27.7	7	28.6	71.4
4	2	80	5	62	16	15	22	18	−7	−11	3	18	15.6	−2	15.7	84.3

Determine orientation (cell K4)

```
=IF(AND(H4<0,I4<0,J4>=0),1,IF(AND(H4<0,I4>=0,J4<0),2,IF(AND(H4>=0,I4<0,J4<0),3,IF(AND(H4>=0,I4>=0,J4<0),4,IF(AND(H4>=0,I
4<0,J4>=0),5,IF(AND(H4<0,I4>=0,J4>=0),6,1))))))
```

Calculate maximum absolute value of error (cell L4)

```
=MAX(ABS(H4),ABS(I4),ABS(J4))
```

Calculate AD (cell M4)

```
=0.866*L4
```

Calculate DE (cell N4)

```
=IF(K4=1,(D4-L4/2-B4),IF(K4=2,(E4-L4/2-C4),IF(K4=3,(G4-L4/2-F4),IF(K4=4,(D4+L4/2-B4),IF(K4=4,(E4+L4/2-
C4),IF(K4=6,(G4+L4/2-F4),333))))))
```

Calculate AE (cell O4)

```
=SQRT(M4*M4+N4*N4)
```

Calculate score (cell P4)

```
=100-O4
```

Table 5. Representation of a spreadsheet showing a practitioner's estimate of particle size distribution for 10 samples.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	ID	Estimated		Lab		Est	Lab	Student - Lab								
2		S	C	S	C	Si	Si	S	Si	C	ORN	AB	AD	DE	AE	Score
3	A	5	10	2	8	85	90	3	−5	2	5	5	4.3	0.5	4.36	96
4	B	10	15	24	16	75	60	−14	15	−1	2	15	13.0	−6.5	14.53	85
5	C	40	29	42	20	31	38	−2	−7	9	1	9	7.89	−2.5	8.19	92
6	D	8	30	12	29	62	59	−4	3	1	6	4	3.5	−1.0	3.61	96
7	E	38	24	41	17	38	42	−3	−4	7	1	7	6.1	−0.5	6.08	94
8	F	55	26	35	42	19	23	20	−4	−16	3	20	17.3	−6.0	18.33	82
9	G	60	16	55	13	24	32	5	−8	3	5	8	6.9	1.0	7.00	93
10	H	64	18	54	21	18	25	10	−7	−3	3	10	8.7	2.0	8.89	91
11	I	78	8	70	4	14	26	8	−12	4	5	12	10.4	2.0	10.58	89
12	J	12	30	3	28	58	69	9	v11	2	5	11	9.5	3.5	10.15	90

Table 6. Methods used to assign scores to students' estimates.

	Student estimate		Lab data					
ID	**Sand**	**Clay**	**Sand**	**Clay**	**USDA texture†**	**Texture estimator score**	**Soil judging score‡**	**Basic soil score§**
A	5	10	2	8	Si	96	100	100
B	10	15	24	16	SiL	85	100	100
C	40	29	42	20	L	92	33	50
D	8	30	12	29	SiCL	96	100	100
E	38	24	41	17	L	94	66	100
F	55	26	35	42	C	82	0	50
G	60	16	55	13	SL	93	100	100
H	64	18	54	21	SCL	91	33	50
I	78	8	70	4	SL	89	66	100
J	12	30	3	28	SiCL	90	66	100

† Si = silt, SiL = silt loam, L = loam, SiCL = silty clay loam, C = clay, SL = sandy loam, SCL = sandy clay loam.
‡ Soil Judging allows + or −5% of sand and clay; full score for correct texture.
§ Basic soils courses give full credit for appropriate texture class and half credit for adjoining textural classes.

Example

Table 5 shows how a practitioner estimated the texture of 10 samples and the comparison is graphically illustrated in Fig. 4. The score tells how closely the estimated values match laboratory results. The orientation tells the major discrepancy of the estimate (Table 3). Discrepancies were in practically all directions, but they underestimated silt (orientation 5) in 4 of the 10 samples. Having knowledge regarding consistently underestimating sand, silt, or clay can provide useful information for students who are learning the texture-by-feel technique. Columns B through E were copied from the MS Excel spreadsheet and estimated and actual data points were plotted (SigmaPlot 2000) on a ternary diagram with a texture triangle background that shows graphically the relation of estimated and actual PSDs. The practitioner got the texture class correct for 6 of the 10 samples (A, B, D, E, G, I). Additionally, Table 6 provides an example of how scores may be calculated compared to the texture evaluator. The approach used for soil judging and basic soils class provides an evaluation of the student's ability but the assessment is based on Boolean logic rather than assessing the skill on a sliding scale.

Figure 5 provides a visual representation of the target laboratory analysis value in the center of the concentric rings of 85, 90, and 95% to understand the variability of values that could yield a given score. The score of 95% crosses four textural classes and the score of 85% crosses six textural classes; however, the score is empirically based on the student's estimation of sand and clay estimates.

Conclusion

The assessment of texture-by-feel is critical for those assessing the skill of an individual, as well as the individual who is working on improving the texture-by-feel skill. This methodology provides a quantitative, reliable, fair, and easy-to-use system for evaluation. When students or practitioners compare their texture estimates with laboratory data, they can enter the values and immediately get their score. Additionally, we can now provide students the major errors and a plot similar to Fig. 4. When all are collected, the lab values are given, and the soil scientists can take this information and feel the samples again and calibrate their analysis.

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