

Who Shines the Brightest?

Lesson STEM Math Connections Grade 4

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(To be integrated in Eureka Math, Grade 4, Module 3, Topic E: Division of Tens and Ones with Successive Remainders)

In this lesson, students will briefly learn the background about how the brightness of the environment is measured in Lux. The class will use an app on the teacher's phone, to record data points of how bright each classroom in the hallway is. Students will record the brightness and use division to calculate the actual Lux value. Then, students will determine which classroom is the brightest, not based on being smart, but based on light illuminance!

Approximately 40 minutes in duration.

Standards Addressed

CCSS: 4.NBT.6

Find whole-number quotients and remainders with up to four-digit dividends and one-digit divisors, using strategies based on place value, the properties of operations, and/or the relationship between multiplication and division. Illustrate and explain the calculation by using equations, rectangular arrays, and/or area models.

Student Learning Objective

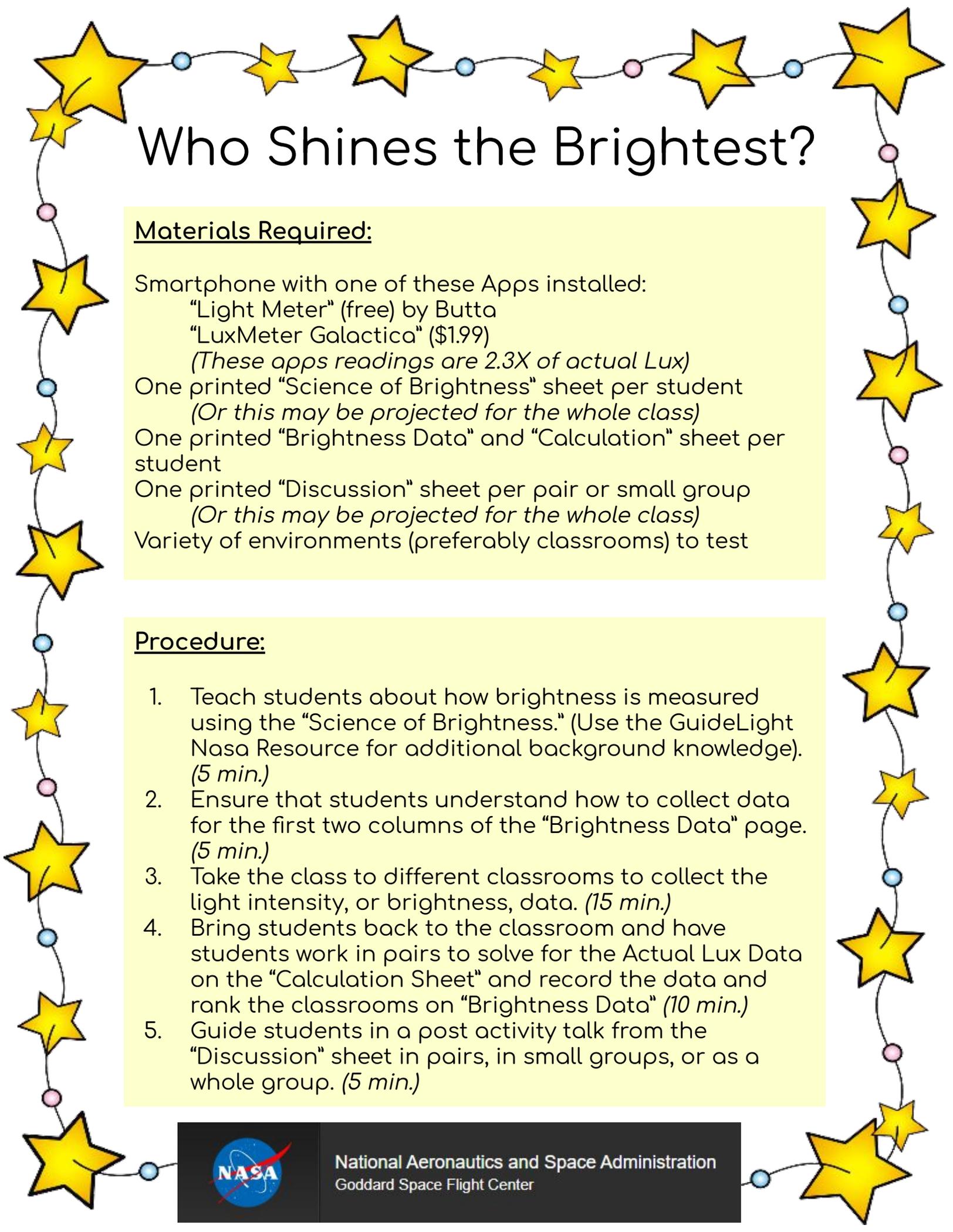
Students will collect and record data.
Students will solve division problems using the standard algorithm, area model, or place value chart based on that data.
Students will numerically rank that data.

Measurable Achievement Goal:

Students will complete the Brightness Data sheet with 85% accuracy.
Students will participate and contribute at least one thought in a post activity discussion.



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Materials Required:

Smartphone with one of these Apps installed:

“Light Meter” (free) by Butta

“LuxMeter Galactica” (\$1.99)

(These apps readings are 2.3X of actual Lux)

One printed “Science of Brightness” sheet per student
(Or this may be projected for the whole class)

One printed “Brightness Data” and “Calculation” sheet per student

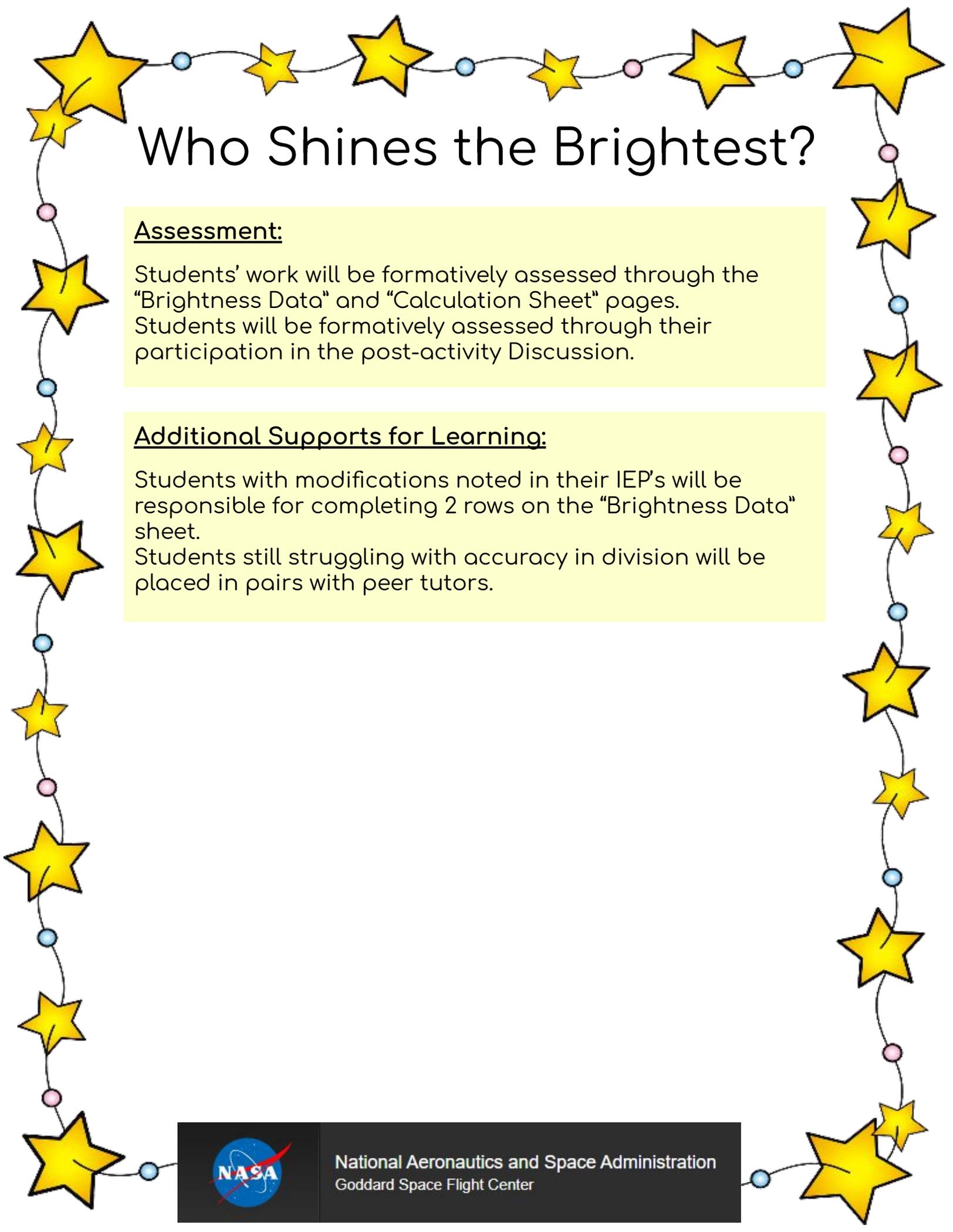
One printed “Discussion” sheet per pair or small group
(Or this may be projected for the whole class)

Variety of environments (preferably classrooms) to test

Procedure:

1. Teach students about how brightness is measured using the “Science of Brightness.” (Use the GuideLight Nasa Resource for additional background knowledge). *(5 min.)*
2. Ensure that students understand how to collect data for the first two columns of the “Brightness Data” page. *(5 min.)*
3. Take the class to different classrooms to collect the light intensity, or brightness, data. *(15 min.)*
4. Bring students back to the classroom and have students work in pairs to solve for the Actual Lux Data on the “Calculation Sheet” and record the data and rank the classrooms on “Brightness Data” *(10 min.)*
5. Guide students in a post activity talk from the “Discussion” sheet in pairs, in small groups, or as a whole group. *(5 min.)*





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Assessment:

Students' work will be formatively assessed through the "Brightness Data" and "Calculation Sheet" pages. Students will be formatively assessed through their participation in the post-activity Discussion.

Additional Supports for Learning:

Students with modifications noted in their IEP's will be responsible for completing 2 rows on the "Brightness Data" sheet. Students still struggling with accuracy in division will be placed in pairs with peer tutors.



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Who Shines the Brightest?

The Science of Brightness

Did you know that scientists have a way to measure the intensity of light! Just like we measure time, with how many hours you are at school, we can measure the brightness outside or in a room. Think about a smartphone, ipad, or computer screen. The brightness of the screen increases and decreases so that our eyes see the screen more comfortably. Smartphones use ambient light sensors to adjust brightness automatically based on the environment's light intensity.

Light intensity is measured in terms of illuminance in units of Lux. If you stand outside at noon in regular daylight conditions, the light intensity, or brightness outside, is about 100,000 Lux. Look at the chart below to see how much Lux is measured during the different times of the day.

		Light Level (LUX)	Foot Candles (FC)
Day Time	Sunlight	107,527	10,000
	Daylight	10,752.70	1,000
	Overcast Day	1,075.30	100
	Very Dark Day	107.53	10
	Twilight	10.75	1
Night Time	Deep Twilight	1.08	0.1
	Full Moon	0.108	0.01
	Quarter Moon	0.0108	0.001
	Starlight	0.0011	0.0001
	Overcast Night	0.0001	0.00001



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Brightness Data

Observe and record data from different classrooms to see what light intensity each one has based on the downloaded app. (Since these apps are 2.3 times higher than an actual, professional light metering system, divide each app value by 2 to be closer to the actual illumination scale).

Teacher's Classroom & Grade Level	App Lux Data	Actual Lux Data (divide App value by 2)	Ranking of Brightness (1st, 2nd, 3rd, or 4th)
_____ & _____			

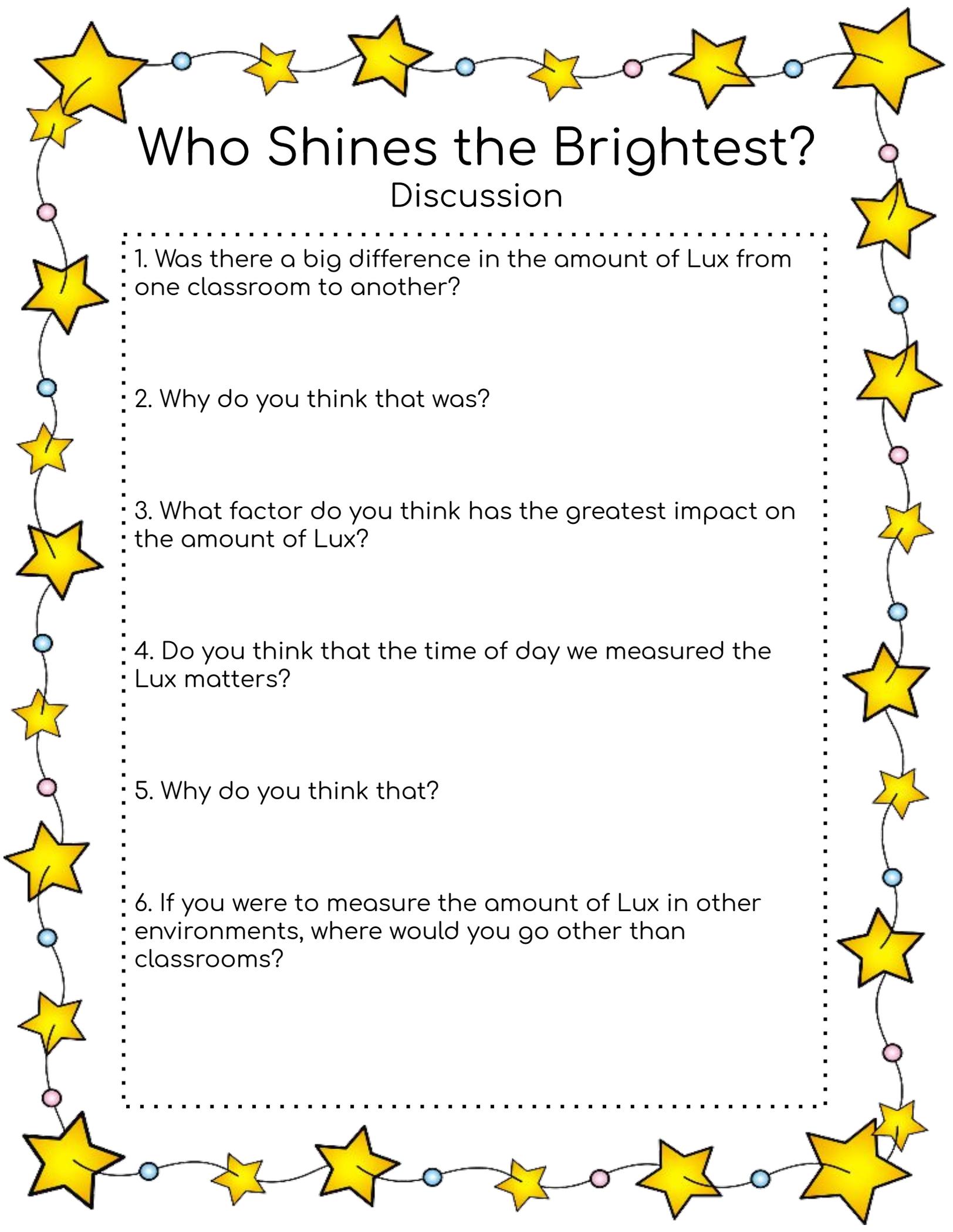


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Calculation Sheet

Since the app on the phone is 2.3 times higher than an actual, professional light metering system, divide each app value by 2 to be closer to the actual amount of Lux. Use the space below to show the work of your calculations. You may use any of the dividing strategies that we have learned in class.

$$\text{App Lux Data} \div 2 = \text{Actual Lux Data}$$



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Discussion

1. Was there a big difference in the amount of Lux from one classroom to another?

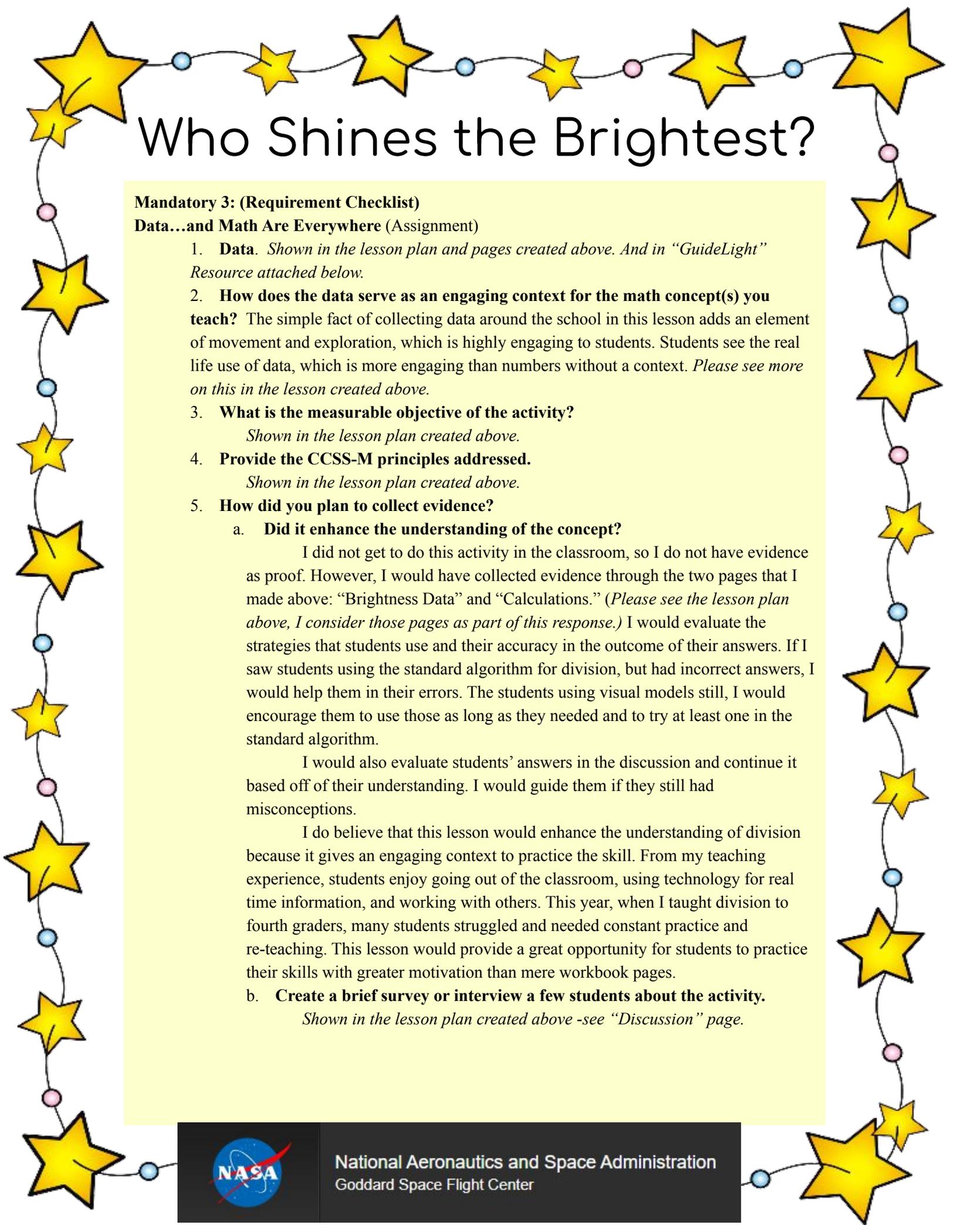
2. Why do you think that was?

3. What factor do you think has the greatest impact on the amount of Lux?

4. Do you think that the time of day we measured the Lux matters?

5. Why do you think that?

6. If you were to measure the amount of Lux in other environments, where would you go other than classrooms?



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Mandatory 3: (Requirement Checklist)

Data...and Math Are Everywhere (Assignment)

1. **Data.** *Shown in the lesson plan and pages created above. And in "GuideLight" Resource attached below.*
2. **How does the data serve as an engaging context for the math concept(s) you teach?** The simple fact of collecting data around the school in this lesson adds an element of movement and exploration, which is highly engaging to students. Students see the real life use of data, which is more engaging than numbers without a context. *Please see more on this in the lesson created above.*
3. **What is the measurable objective of the activity?**
Shown in the lesson plan created above.
4. **Provide the CCSS-M principles addressed.**
Shown in the lesson plan created above.
5. **How did you plan to collect evidence?**
 - a. **Did it enhance the understanding of the concept?**

I did not get to do this activity in the classroom, so I do not have evidence as proof. However, I would have collected evidence through the two pages that I made above: "Brightness Data" and "Calculations." (*Please see the lesson plan above, I consider those pages as part of this response.*) I would evaluate the strategies that students use and their accuracy in the outcome of their answers. If I saw students using the standard algorithm for division, but had incorrect answers, I would help them in their errors. The students using visual models still, I would encourage them to use those as long as they needed and to try at least one in the standard algorithm.

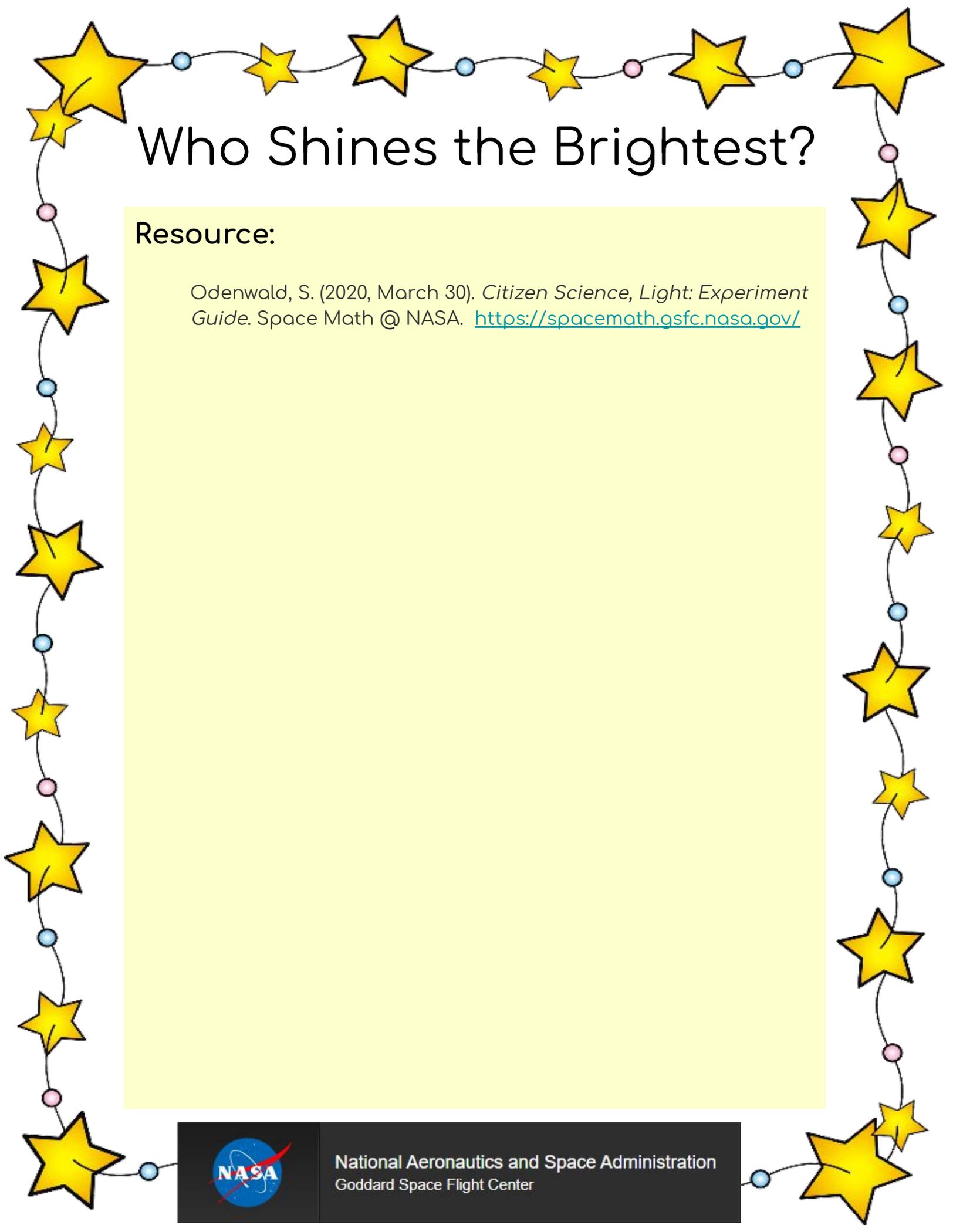
I would also evaluate students' answers in the discussion and continue it based off of their understanding. I would guide them if they still had misconceptions.

I do believe that this lesson would enhance the understanding of division because it gives an engaging context to practice the skill. From my teaching experience, students enjoy going out of the classroom, using technology for real time information, and working with others. This year, when I taught division to fourth graders, many students struggled and needed constant practice and re-teaching. This lesson would provide a great opportunity for students to practice their skills with greater motivation than mere workbook pages.

- b. **Create a brief survey or interview a few students about the activity.**

Shown in the lesson plan created above -see "Discussion" page.





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Resource:

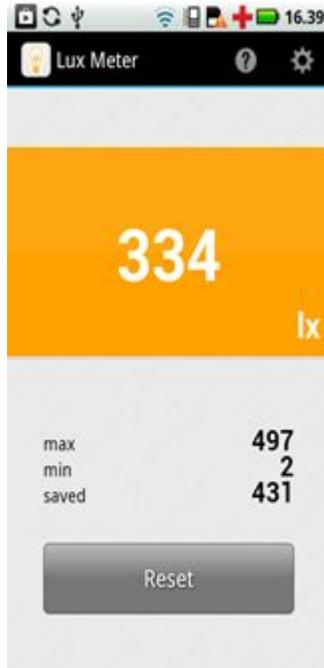
Odenwald, S. (2020, March 30). *Citizen Science, Light: Experiment Guide*. Space Math @ NASA. <https://spacemath.gsfc.nasa.gov/>



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Light Intensity



How it Works

Smartphones use light meters to set the exposure speed and the ISO 'film speed' of the digital camera. These metering systems are created by 'spotting' the pixels in a portion of the camera array chip to measure the incident light that falls on them. This information in the 'spot metering' mode is used to set the exposure speed of the camera. The f-stop of a smartphone camera is fixed usually at f/2 (fast) or f/2.4 (slow) or so, unlike in digital cameras. The roughly half-stop difference in cameras corresponds to the faster cameras seeing 50% more light, and so they perform better under low light level conditions.

Smartphones also use ambient light sensors as stand-alone devices to determine how bright the display needs to be for comfortable viewing. These sensors are not very directional unlike the camera light metering system. Most smartphone ambient light sensors are photodiodes whose current flow varies with the amount of applied light.

The following apps measure light intensity in terms of illuminance in units of Lux. Physically, illuminance is related to the flux of radiant energy per square meter, and is the product of the emission spectrum and the normalized spectral response function of the human eye, and summed over all wavelengths to get the total energy flux.

LUX RATING CHART			
	Light Level (LUX)	Foot Candles (FC)	
Day Time	Sunlight	107,527	10,000
	Daylight	10,752.70	1,000
	Overcast Day	1,075.30	100
	Very Dark Day	107.53	10
	Twilight	10.75	1
Night Time	Deep Twilight	1.08	0.1
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Because the flux of sunlight during noon daylight conditions is about 100,000 Lux, and this corresponds to a solar insolation of about 1000 watts/m², we can estimate that 1 lux = 100 watts/m². A 60-watt incandescent light bulb might generate 850 lumens. But since 1 lux = 1 lumen/1 m², if the bulb is at the center of a sphere with a surface area of 16 square meters, you have 850/16 = 53 lux. Generally a 60-watt bulb does not produce 60 watts of luminous energy but significantly less, so the conversion factor above does not apply.

App Descriptions



LuxMeter Galactica – (\$1.99) If you professionally deal with lighting or simply want to measure the illumination of the certain place, and you do not have a special device, you can use this application to make light measuring, combine the values obtained (lux) with a photo of your place of measurement, add your comments and save your image in photo album or send via e-mail. This app is used for evaluative light measuring and is not a substitute for specialized device.



Light Meter (free) by Butta. A camera view allow you to view the area you want to measure. You can choose between the front and rear camera. Additionally the shutter speed, ISO and focal are displayed.

Relative Performance Tests

Check to see if apps give consistent reading for same brightness. Static measurement of identical light source. Camera sensor facing white poster board placed horizontally outdoors on a cloud-free day and filling FOV of camera.

App Name/icon	Metering Method	Pitch black room	March 24 2:00pm sun @ 52°	March 24 3:00pm Sun @ 48°	March 24 4:00pm Sun @ 35°	March 24 5:30pm Sun @21°
	Camera view \$1.99	7 lx	202,000	177,000	78,600	42,900
	Camera view Free	0 lx	212,738	186,137	87,595	48,023

Absolute Measuring using Professional-grade Photometers.

The difference between the camera apps and professional metering systems is that the apps use the primitive light sensor on the camera while the professional systems use a high-grade photoconductor system and filtering system to make the measurements.

We need to measure our meters at levels above 10,000 lux for solar daytime conditions. For this we used a professional-grade light metering system: Extech Instruments LT300 Light Meter (Amazon: \$129.00). The Extech LT300 light meter measures up to 40,000 Fc (or 400,000 Lux) utilizing a remote light sensor connected via 12 in. coiled cable (expandable to 24 in.). An LCD readout displays a digital calculation and complementary analog bar graph for quick assessments. (http://www.extech.com/resources/LT300_UM.pdf). Measurement repeatability is claimed to be +/- 2% and accuracy +/- 5%.

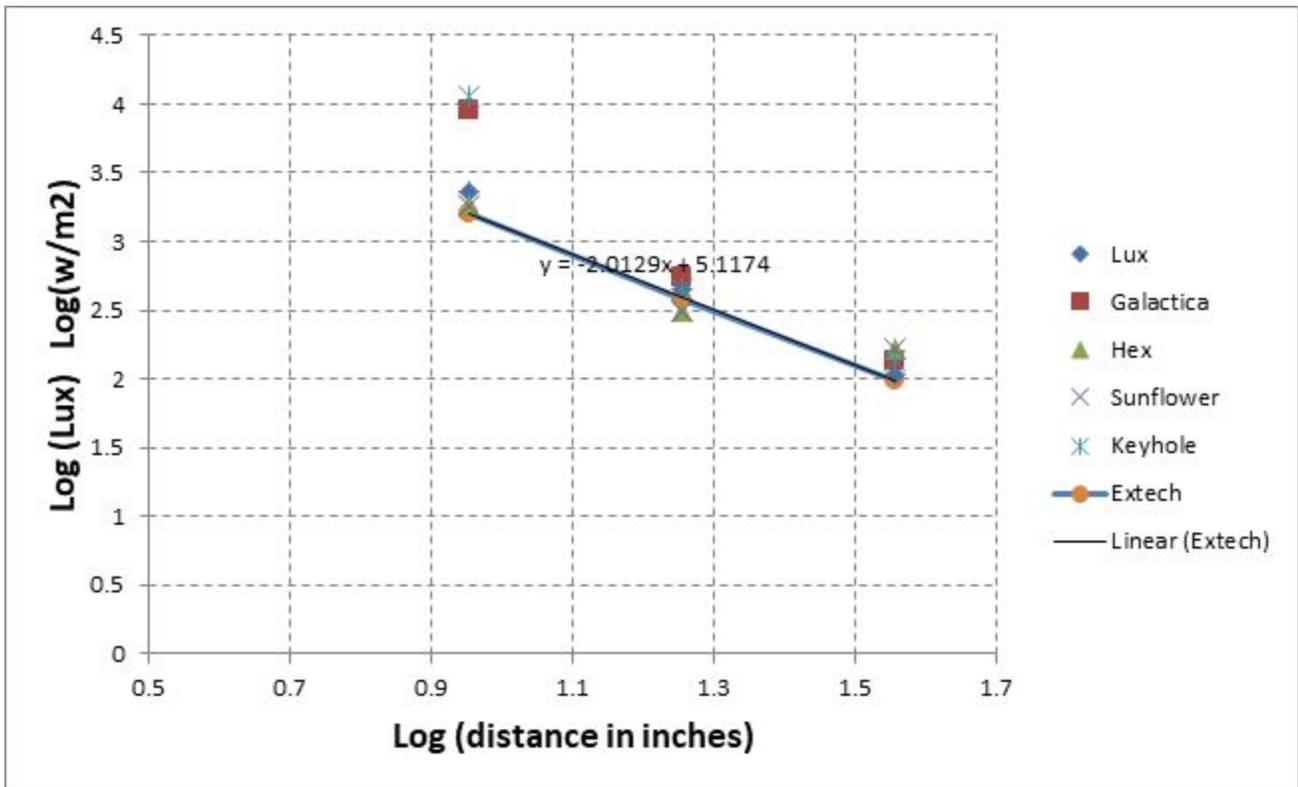
Next we measured a standard 60-watt bulb placed at different distances from the smartphone and the professional metering systems. The set up was in a darkened room where only the light bulb provided the illumination. This was repeated four times with four different 60-watt bulbs.

App	Bulb A	Bulb B	Bulb C	Bulb D	Averages with +/- 1 sigma
Lux Light meter -2	218	354	218	281	267 +/- 64
Galactica -1	216	276	345	276	278 +/- 53
Extech	403	403	403	405	403 +/-1

The grand average for the five apps is 276 +/- 50 Lux but Extech says 403 +/- 1 Lux so at this light intensity, the scale factor $\text{Extech/app} = 1.47 \pm 0.25$ so that the apps predict a 47% lower Lux than the professional metering systems. It is also interesting that the watt-meter says that a 60-watt bulb produces 22 watts/m² of illumination.

Check linearity of the scale factor by using inverse-square law with one 60-watt bulb for all metering systems. The decrease at each step by a factor of two should be a factor of 4 in lux

App	Zero Light	9-inches	18-inches	36-inches	72-inches	144-inches
Lux Light meter -Lux	0	2314	445	107	37	27
Galactica	0	9000	552	138	46	34
Extech	0	1580	386	97	39	16



Plotted points are only those from within 36-inches of the bulb to avoid background scattered light that artificially elevates the lux values. The best-fit linear equation shows that the power-law exponent is very close to -2.0 for the Lux vs distance (upper line) and flux vs distance (lower) data so the inverse-square law is verified to within the measurement errors so long as the light intensity remains above about 100 Lux.

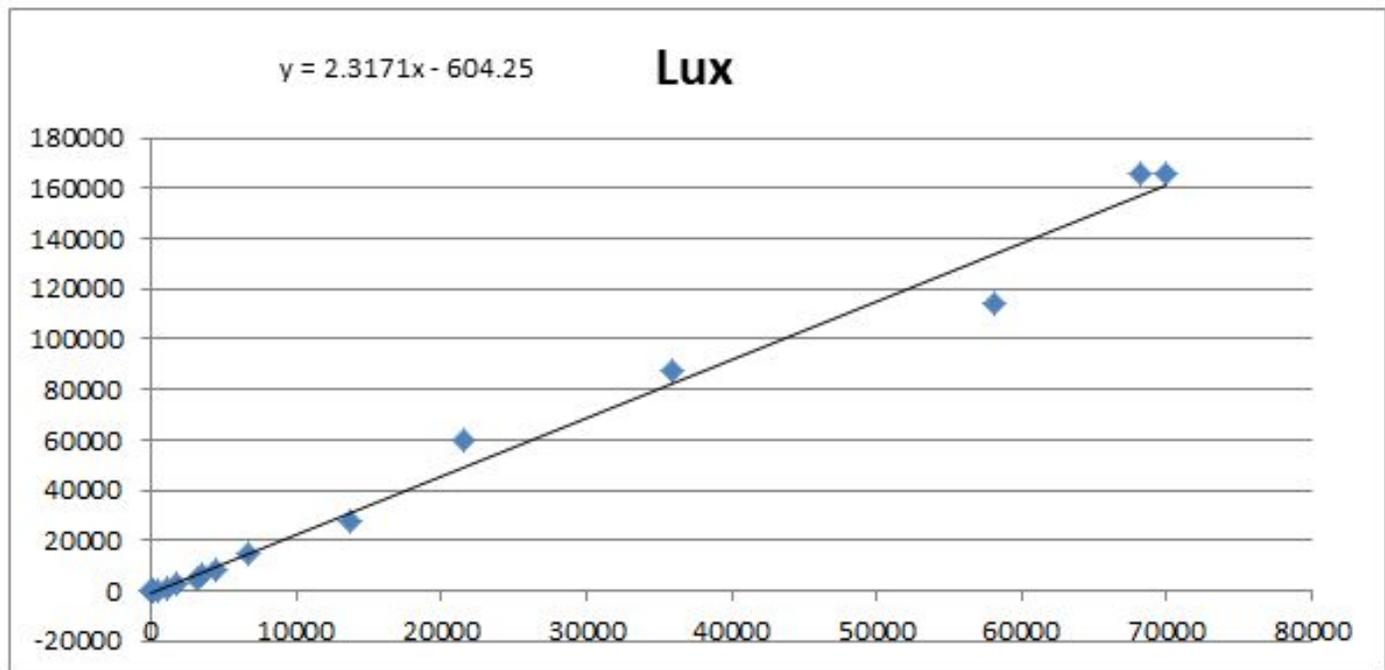
As before, the smartphone app light meter measurements were made sequentially, with the camera lens facing a horizontal, white sheet of paper in full sunlight. The Extech and DT-3701 meters were then placed at the center of the paper with the sensors facing up and pointing to local zenith. A variety of external light measurements were made of direct and indirect sunlight.

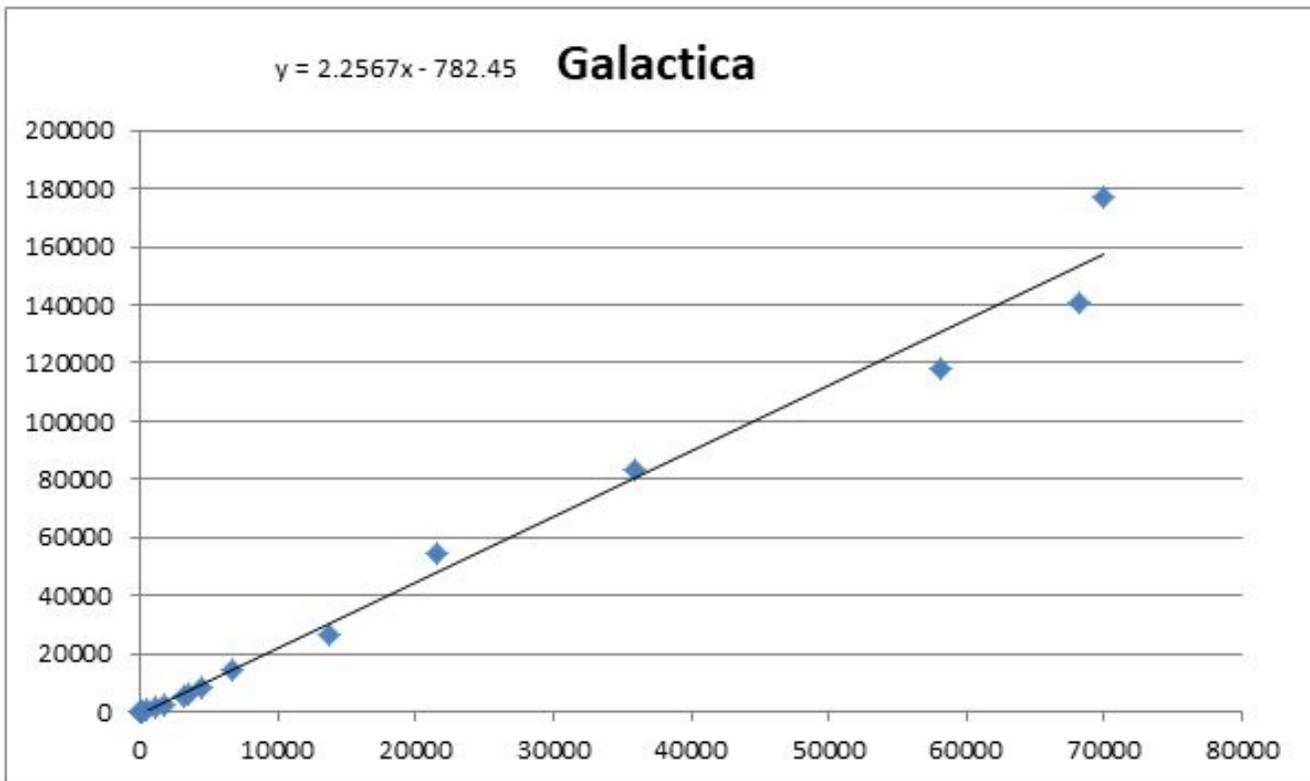
Type	Extech	Lux Light meter	Galactica
direct	16	27	31
direct	39	37	43
direct	97	107	135
indirect	130	173	138
direct	386	445	549
indirect	1150	1153	1700
indirect	1709	2392	2300

indirect	3125	4560	5000
indirect	3462	6500	6000
indirect	4430	8490	8600
indirect	6700	14879	14700
direct	13800	28082	26200
direct	21600	59562	54400
direct	36000	87595	83200
direct	58200	114544	118000
direct	68200	165461	141000
direct	70000	165461	177000

□

The response of each app relative to the calibrated Extech scale were plotted and fitted. The following two plots are for the camera imaging systems where you can clearly see the light source on the screen with the metering circle drawn around the center.





It is clear that these apps yield a uniform scaling that is between 2.25 and 2.36, which says that for bright light sources, the apps predict a Lux value that is about 2.3 times higher than an actual, professional light metering system over an illumination range from 0 to 70,000 Lux. This means it is a simple matter to take Lux values from a camera light app and convert it to an actual illumination scale by dividing the app values by 2.3.