Subject-Spotting Experimental Method for Gen Z

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***Abstract* –The technological changes along with the psychological and structural changes of the young generation (Gen Z) require adjustment of the educational methods. In this regard, the paper presents a way of explaining uncertainty of measurements by the use of experimental subject-spotting. The method consists in splitting – subject-spotting – a complex subject into small parts that require lower sustained attention and are easier to be understood and memorized. Each subject-spot uses the link between theory and practice, allowing multi-tasking behaviours. The focus is on obtaining quick results.**

The practical application of experimental subject-spotting of uncertainty is based on the measurement of the water flow through a pipe by the method of time volume collection. The flow rate measurement represents the grounding for developing several experimental subject-spots that explain the uncertainty of analogue and digital readings, of repeated measurements, the level of confidence, expanded uncertainty and the propagation of uncertainty. The mathematical model and program, some final considerations and further reading suggestions open other directions of studying uncertainty, eventually covered by other subject-spots.

***Keywords* – experimental method, subject-spotting, uncertainty, flow rate measurement, Gen Z.**

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1. Introduction

The technological advances and the Web are responsible for two of the main directions in which our world evolves: the interconnection between information, individuals and things and the tendency of extending the reality into a virtual world [1]. The high level of technology and the huge amount of information that is instantly available is changing our lifestyle towards quickness, shortness, flexibility. The young Gen Z generation that migrates today into adulthood expects that everything happens very fast, instantly if possible [2]: they communicate by under-constructed and over-punctuated sentences, ask for quick answers, instant acquisition of knowledge and immediate reward. If things don't happen fast enough they prefer to quit and look for something else. Gen Z doesn't have the patience to pay sustained attention or to grub for an answer to solve a problem. For them, a lower accuracy is usually acceptable to obtain a higher speed.

At the cognitive level, compared to the older generations, the cohabitation with Internet determines structural changes of the brain towards [3]:

- fast attention shifting, increased distractibility and multi-tasking behaviours,
- shallower processing of information,
- decreased sustained attention, contemplation and deliberation,
- decreased information retention,
- focus on immediate reward.

The young generation must use these characteristics to live into a world of static and dynamic interconnections between people, smart equipment and information [1]. It must develop the ability to take the correct decisions based on a high inflow of complex, uncertain and variable information that is available in real-time. For them, it is mandatory to be able to use the available equipment, to collect and interpret the data, to analyse the results and to report them properly [4, 5].

In this context, the understanding, evaluating and handling of the uncertain information is a very important issue. At the same time, it is a challenge to explain complex issues to students. The paper explores a new way of explaining uncertainty of measurements to the Gen Z students.

2. The method of experimental subject-spotting

The traditional way of introducing the concept of uncertainty in laboratories is based on the theory of statistics, probability and Gaussian distribution [6], as recommended by the International Organization of Standardization (ISO) through the two guides known as GUM [7] and VIM [8]. Such an approach requires sustained attention on a complex subject, making it difficult to be followed and understood by the impatient and distractible generation of today.

Therefore, with the aim to adapt to the cognitive structure of the modern students, a simpler fragmented approach is adopted. The approach is based on the student's final needs: the practical estimation of uncertainty in a laboratory and the calculation of its propagation [6]. The emphasis is especially on the practical application and less on the mathematical considerations. The scope would be to give an instrument for handling uncertainties and to create the background for studying other important experimental issues and deepening the theoretical and mathematical considerations.

Therefore, the method proposed in the paper is based on an experiment and focuses on the practical use of the concept of uncertainty in laboratories. To cope with the high distractibility of the students and keep the interest open and the attention concentrated on the subject, the method of subject – spotting is used. The attention of the students is spotted (switched) sequentially on different issues. Information is given in small pieces, which are better suited to the young generation's structure. Each issue is independent, so that it can be explained and understood easily, prior to losing the students' concentration.

The content of each subject-spot is based on David Kolb's concept [9] of experimental learning. According to it, short experiments, rapid observations, reduced deliberations and selective theoretical considerations are spotted to reach an immediate solution.

The outcomes of several subject-spots are used for solving different subjects, step-by-step. Rather than showing a huge, discouraging picture from the beginning and then fill it with information, several subject-spots are used to enlarge the picture gradually. The attention is shifted from one spotted subject to another until all the subjects are addressed. Along with covering the spotted subjects, the link between them is created to acquire the desired level of cognition (Figure 1.).

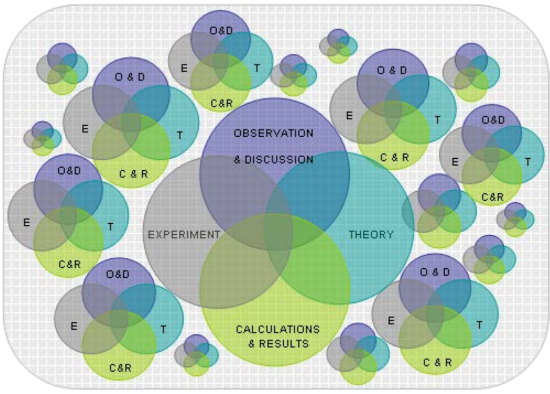


Figure 1. Learning by the method of experimental subject-spotting

The step to a deeper understanding can be continued by further spotting the subjects and adding new small pieces of affordable information to the picture.

The subject - spotting approach may be very helpful in education, as it follows the way in which information is acquired, stored and accessed by the Gen Z students. Instead of memorizing the information itself - which is easily available on the Internet "external memory" [10] - the students tend to remember where to find it, how to access it, when to access it and how to use it. Rather than memorizing the solution, they memorize the path to find it. Spotted-subjects can be easily "detected" within the network and this makes them more suited nowadays.

3. Experimental subject-spotting of uncertainty

As the subject of uncertainty is a very complex one, subject-spots can be used to answer to the practical problems that occur most often in laboratories: What is the uncertainty of a single reading? What is the uncertainty of repeated measurements? How do uncertainties propagate?

The main topics on uncertainty that answer these questions are organized according to the scheme shown in Figure 2. According to this scheme are defined the spotted-subjects and the link between them.

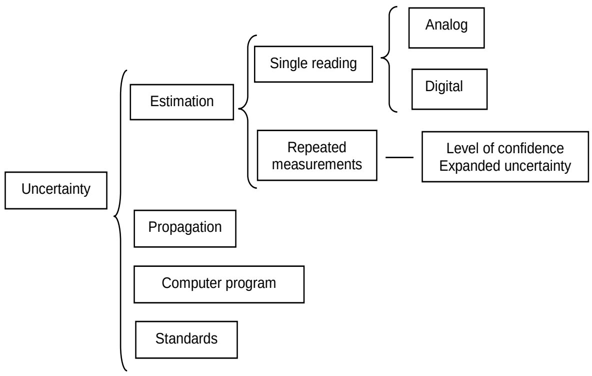


Figure 2. Explaining uncertainty by experimental subject-spotting

The sequence of subject-spots which we considered to explain the topics emphasized in Figure 2. are given in Table 1. Each subject-spot includes its own link between theory and practice by covering several steps: an experiment (E), observations and discussions (O&D), theoretical considerations (T), calculations and results for the considered experiment (C&R). The result of one step is used to introduce the following one. It is not mandatory to have all the four steps in a subject-spot, nor to follow them in a strict order. For example, it is possible that within a subject-spot there is an experimental step but no calculation step.

Table 1. Subject-spots and steps used to explain uncertainty in laboratories

Subject-spot	E	O&D	T	C&R
1. Introductory spot	√	√	√	-
2. Uncertainty of analogue reading	√	√	√	√
3. Uncertainty of digital reading	√	√	√	√
4. Uncertainty of repeated measurements	√	√	√	√
5. Level of confidence. Expanded uncertainty	√	√	√	-
6. Propagation of uncertainty	√	√	√	-
7. Mathematical model and program	-	√	√	√
8. Uncertainty standards and further reading	√	√	-	-

E – experiment; O&D – observations and discussion;
T – theoretical considerations; C&R – calculations &results.

4. Practical application of experimental subject-spotting of uncertainty

A practical application is used to introduce, explain and strengthen each subject-spot of Table 1. and to develop the link to other spots. The experiment consists in measuring the water flow rate through a pipe by the method of time volume collection, which supposes the measurement of the necessary time to accumulate a specific amount of water.

4.1. Spot 1. Introductory spot – experimental bench, flow rate measurement and uncertainty

EXPERIMENT: The experiment uses the hydraulic bench from Armfield (see Figure 3.). The bench provides the possibility to recirculate water and to measure the volumetric water flow rate [11]. The flow rate measurement is made by the method of time volume collection: a water volume chosen by the experimenter is accumulated into a volumetric tank by closing a ball valve (Figure 3-c.). The volume is measured outside the tank, on the sight glass (Figure 3-a.). The time taken to accumulate the chosen volume in the tank is measured with a computer's app stopwatch.

Figure 3. The experimental hydraulic bench

The flow rate is then calculated from the two measurements as:

$$Q = \frac{V}{t} \tag{1}$$

where:
Q - water flow rate, in liters per second (l/s),
V - volume of water accumulated, measured on a sight glass outside the tank, in liters (l),
t - time, measured with a stopwatch, in seconds (s).

OBSERVATION & DISCUSSION: To carry out the measurement, it is needed to have measurement equipment, a measurement procedure and experimenting skills. These, along with other known or unknown factors influence the outcome of the measurement and give an uncertainty to the measured value [12, 13].

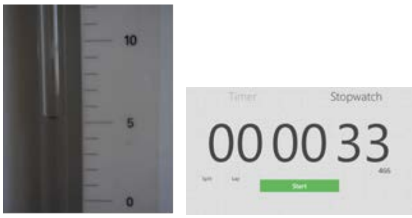
THEORY: The uncertainty of measurement, with a degree of belief, estimates how good the measured value is, without knowing the true value. A complete result of the measurement is expressed as $x \pm u(x)$, where x is the best estimate of the value and $u(x)$ is the uncertainty (standard uncertainty) of the measurement. Both values are expressed in the measurement unit of the measured value (the measurand). The interpretation of the result states that the true value (which is unknown) lies somewhere in the range from $x - u(x)$ to $x + u(x)$ [6, 13].

After the overview of the introductory spot, the experiment is split into several spotted subjects to explain the different issues related to the concept of uncertainty: uncertainty of single reading (analog, digital), uncertainty of repeated measurements, level of confidence, propagation of uncertainty.

4.2. Spot 2. Uncertainty of analogue reading

EXPERIMENT: A water volume of 5 liters is accumulated into the volumetric tank by closing the ball valve (Figure 3-c.) and measured on the sight glass that is outside the tank (Figure 3-a.).

OBSERVATION & DISCUSSION: Based on the observation that the smallest scale division on the sight glass is of 1 liter (Figure 4-a.), a discussion is made about the estimation of smaller values and the uncertainty of the result.



(a) (b)

Figure 4. The scale for volume reading and display for time reading

THEORY: The uncertainty for single reading of analogue values is (at least) ± 1/2 of the smallest scale division [14].

CALCULATION & RESULTS: The reading of a volume of 5 liters on a scale that has the smallest division of 1 liter gives the result of 5.0 ± 0.5 liters. This means that the measurand is somewhere within the range [4.5 … 5.5] liters (one cannot tell exactly where the true value lies).

4.3. Spot 3. Uncertainty of digital reading

EXPERIMENT: There is measured the time necessary to accumulate the volume of 5 liters. For the measurement of time there is a stopwatch app of a computer used that has a digital display (Figure 4-b.). Within the experiment, the reading of the time was 33.466 seconds.

OBSERVATION & DISCUSSION: It is observed that the smallest division of the stopwatch shows 0.001 seconds. The uncertainty of the digital reading is discussed, especially its low value.

THEORY: The uncertainty for single reading of digital values is (at least) ± the smallest unit shown on the digital display [14].

CALCULATION & RESULTS: Considering the reading uncertainty of the digital display, the result of the time measurement with the stopwatch is:

$$t = 33.466 \pm 0.001 \text{ seconds} \quad (2)$$

which means that the true value is within the range [33.465 … 33.467] seconds. An unbelievably small uncertainty!

4.4. Spot 4. Uncertainty of repeated measurements

EXPERIMENT: Wondering about the high precision of the stopwatch, the experiment is repeated for several times in the same conditions to verify whether the result can be reproduced. By repeating the experiment for 10 times, different results were obtained (see Table 2.).

Table 2. Results of time measurements for repeated experiments

Experiment *i*	**Water volume** *V* [m^3]	**Time interval of water accumulation** *t* [sec]
1	5	33.466
2	5	32.430
3	5	33.461
4	5	33.269
5	5	33.105
6	5	33.061
7	5	33.870
8	5	33.308
9	5	33.324
10	5	34.107

OBSERVATION & DISCUSSION: It is observed that the results of the 10 different measurements exceed the uncertainty of seconds given by the digital reading of the stopwatch. The main cause of the differences is the experimenter's reaction time for starting and stopping the stopwatch. The impossibility to conduct a perfect measurement is discussed and deepened. This leads to the conclusion that the result of any measurement is influenced by a multitude of known and unknown factors, such as: the measurement equipment, the procedure of the experiment, the skill of the experimenter (how the experiment is conducted), the nature of the measurand and other outside influences [12, 13]. Such factors increase the uncertainty of measurement.

THEORY: In the case of repeated measurements, the uncertainty can be determined from the data scatter, based on the probability distribution frequency. Note that the evaluation – known also as Type A evaluation – neglects other sources of uncertainty that may affected the result. Other methods should also be used to consider influences as those coming from the unknown systematic errors [7].

A visual check of the data consistency should be made to test the compliance to the Gaussian distribution, which is the most common situation in the scientific experiments.

If the measurements are not following the rule of Gauss, the number of experiments under the same conditions must be increased. If the distribution is still not Gaussian, other methods of determining the uncertainty should be applied.

It is also recommended to remove the significantly different values (the outliers), as they may be caused by mistakes occurred during measurements and may alter the results. Other measurements should be taken instead.

After the visual check of the data scatter about a normal (Gaussian) distribution, the following calculations define the uncertainty [7, 8]:

1. The mean value of the measurements, which represents the best estimate of the expected value:

$$\bar{x} = \frac{1}{n} \cdot \sum_{i=1}^{n} x_i \qquad (3)$$

where:
n - the number of measurements repeated in the same conditions,
$\bar{x}$ - the average value of the n measurements.

2. The experimental standard deviation, given by the square root of the measurements. It estimates the variance of the probability distribution, indicating the variability of the measured values and their dispersion about their mean. The experimental standard deviation is calculated according to:

$$\sigma_{x_i} = \sqrt{\frac{1}{n-1} \cdot \sum_{i=1}^{n} \left(x_i - \bar{x}\right)^2} \qquad (4)$$

This value shows that 68% of the measured values are within the interval between $\bar{x} - \sigma_{x_i}$ and $\bar{x} + \sigma_{x_i}$, 95% within the interval $\bar{x} \pm 2\sigma_{x_i}$ and 99,7% within $\bar{x} \pm 3\sigma_{x_i}$. This three intervals are used for a second check of data compliance to the normal distribution. It is verified that at least this percentages are obtained.

3. The experimental standard deviation of the mean, which defines the standard uncertainty of the mean (known as type A variance or type A standard uncertainty) for Gaussian distributions. Its meaning is to show how well the best estimate - the mean value from Eq. (3) - estimates the expected value.

The standard uncertainty is calculated from:

$$u(\bar{x}) = \frac{\sigma_{x_i}}{\sqrt{n}}, \qquad (5)$$

or, explicitly:

$$u(\bar{x}) = \sqrt{\frac{1}{n \cdot (n-1)} \cdot \sum_{i=1}^{n} \left(x_i - \bar{x}\right)^2} \qquad (6)$$

This value shows that there is a 68% probability that the mean value is within the interval between $\bar{x} - u(\bar{x})$ and $\bar{x} + u(\bar{x})$.

In Eq. (5) or Eq. (6), the standard uncertainty is expressed in the units of the measurand. Alternatively, it may be expressed as fractional uncertainty, dimensionless:

$$u = \frac{u(\bar{x})}{\bar{x}}, \qquad (7)$$

or as a percentage uncertainty:

$$u_{\%} = \frac{u(\bar{x})}{\bar{x}} \cdot 100 \qquad (8)$$

CALCULATION & RESULTS:

For the visual check of the data consistency, the scatter-plot of the measured data is drawn (Figure 5.). As shown in Figure 5., the data is gathered in the middle of the domain, suggesting a normal distribution.

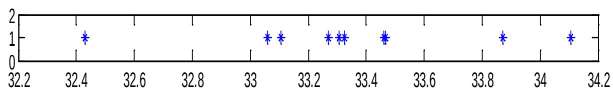


Figure 5. The scatter-plot of the measured values

Using the data of the repeated measurements (Table 2.), there are calculated:

- the best estimate (the mean value) from Eq. (3):

$$\bar{t} = 33.340 \text{ seconds},$$

- the experimental standard deviation from Eq. (4):

$\sigma_{t_i} = 0.455$ seconds.

The second data consistency check shows that 70% of the measurements are within the interval $\bar{x} \pm \sigma_{x_i}$, 100% within $\bar{x} \pm 2\sigma_{x_i}$ and consequently also 100% within $\bar{x} \pm 3\sigma_{x_i}$. The results suggest a normal distribution, additional measurements being unnecessary.

The uncertainties are then determined:

- the standard uncertainty (the experimental standard deviation of the mean) from Eq. (5):

$$u(\bar{t}) = 0.144 \text{ seconds}$$

- the fractional uncertainty, from Eq. (7):

$$u = 0.0043$$

- the percentage uncertainty, from Eq. (8):

$$u_{\%} = 0.43\ \%.$$

Note that for calculating uncertainties, the rounding of numbers must be made up to the next highest figure [13].

The result of the repeated time measurement with the stopwatch gives:

$$t = 33.340 \pm 0.144 \text{ seconds} \qquad (9)$$

Alternatively, the result may be given as:

$$t = 33.340 \text{ seconds } \pm 0.43\% \qquad (10)$$

which means that the measurand is within the range [33.196 … 33.484] seconds. This uncertainty is larger than the one for a single digital reading.

4.5. Spot 5. Level of confidence in uncertainty. Expanded uncertainty.

OBSERVATION & DISCUSSION: Based on the observation that different ranges of uncertainty were obtained, a discussion is made to introduce the topic of confidence in the results.

THEORY: To the uncertainty of the measurement corresponds a level of confidence which shows what is the chance that the true value really lies in the range from $x - u(\bar{x})$ to $x + u(\bar{x})$. A complete result of a measurement is given by the statement [6, 13]:

$$\text{“ } x \pm u(\bar{x}) \text{ with a confidence of } S\ \% \text{ “}, \qquad (11)$$

where:
x - the best estimate of the value, from Eq. (3),
u - the standard uncertainty, from Eq. (6),
S - the level of confidence, in percentage.

The level of confidence shows the degree of belief that the true value lies within the given limits. It corresponds to a risk $\alpha = (100 - S)\%$ that the true value is not within the range from $x - u(\bar{x})$ to $x + u(\bar{x})$. For a Gaussian distribution, which is usual in most scientific experiments, the level of confidence for the standard deviation is 68% [6].

The level of confidence S % may be increased by enlarging the range within which the true value lies. This is made by defining an extended uncertainty U, as [7, 12]:

$$U = k \cdot u(\bar{x}), \qquad (12)$$

where:
U - the extended uncertainty, in the units of the measurand as fractional uncertainty or dimensionless,
k - the coverage factor, dimensionless,
$u(\bar{x})$ - the standard uncertainty, in the same units as the extended uncertainty.

The coverage factor is used to change the level of confidence in the result. Assuming a normal distribution, who gives a level of confidence of 68% for the experimental standard deviation, $k = 2$ gives a level of confidence of 95%, $k = 2.58$ gives a level of confidence of 99% and $k = 3$ gives a level of confidence of 99.7% [13]. Usually, the accepted level of confidence is 95% (a risk of 5%) for technology [12].

CALCULATION & RESULTS: Based on the standard uncertainty calculated in the former spot, the expanded uncertainty is calculated from Eq. (12) for the three coverage factors. The results for the studied case (see Table 2.) are given in Table 3.

Table 3. Expanded uncertainty for time measurement

Coverage factor	**Level of confidence**	**Risk**	**Expanded uncertainty of time measurement**
k, dimensionless	S, %	α, %	U, seconds
1.00	68.0	32.0	0.144
2.00	95.0	5.0	0.288
2.58	99.0	1.0	0.370
3.00	99.7	0.3	0.432

Considering the level of confidence, the complete result of the measurement of the time interval of water accumulation result from Table 3., according to Eq. (11).

4.6. Spot 6. Propagation of uncertainty

OBSERVATION & DISCUSSION: After determining the uncertainty for the volume and time measurement, the problem is to calculate the uncertainty for the result of the division of the two values. The discussion is made around the way in which the uncertainties from measurements may be combined to obtain the uncertainty of the result.

THEORY: Considering two measurements x_1 and x_2 that have the uncertainties u_1 and u_2, the result $y = f(x_1, x_2)$ of combining these measurements has an uncertainty $u_y = f(u_{x_1}, u_{x_2})$ that depends on the individual uncertainties of the measurements simplified. For models that involve simple operations, reduced rules of the expressions for combined uncertainties can be used [12, 15]. Table 4. includes the standard uncertainty of the result for the main combinations between $x_1 \pm u_1$ and $x_2 \pm u_2$.

Table 4. Propagation of uncertainties for the combination of two measurements

$y = f(x_1, x_2)$	$u_y = f(u_{x_1}, u_{x_2})$
$x_1 + x_2$	$\sqrt{u_{x_1}^2 + u_{x_1}^2}$
$x_1 - x_2$	$\sqrt{u_{x_1}^2 + u_{x_1}^2}$
$x_1 \cdot x_2$	$\lvert x_1 \cdot x_2 \rvert \cdot \sqrt{\left(\frac{u_{x_1}}{x_1}\right)^2 + \left(\frac{u_{x_2}}{x_2}\right)^2}$
$\frac{x_1}{x_2}$	$\left\lvert \frac{x_1}{x_2} \right\rvert \cdot \sqrt{\left(\frac{u_{x_1}}{x_1}\right)^2 + \left(\frac{u_{x_2}}{x_2}\right)^2}$

CALCULATION & RESULTS: The determination of the flow rate by the method of time volume collection consists in solving Eq. (1) by using the results of the volume and time measurements from the prior subject-spots (5 ± 0.5 l; 33.34 ± 0.144 s with a confidence of 68%). The best estimate results:

$$Q = \frac{V}{t} = \frac{5}{33.34} = 0.15 \text{ l/s} \quad (13)$$

According to Table 4., the combined standard uncertainty of the water flow rate is calculated from the standard uncertainty of time measurement and the volume measurement, giving:

$$u_Q = Q \cdot \sqrt{\left(\frac{u_V}{V}\right)^2 + \left(\frac{u_t}{t}\right)^2} \quad \text{l/s} \quad (14)$$

$$u_Q = 0.15 \cdot \sqrt{\left(\frac{0.5}{5}\right)^2 + \left(\frac{0.144}{33.340}\right)^2} = 0.015 \quad \text{l/s} \quad (15)$$

The result of the flow rate measurement by the time volume collection method is:

$$Q = 0.15 \pm 0.015 \text{ l/s}$$
with a confidence level of 68% (16)

This means that there is a 68% probability that the flow rate obtained by time volume collection lies in the range 0.135 to 0.165 l/s. The fractional uncertainty calculated from Eq. (7) is u = 0.1 and the percentage uncertainty from Eq. (8) is $u\%$ = 10 %.

Considering different levels of confidence, the result of the flow rate measurement may be given as:

- 0.15 ± 0.015 l/s, confidence level of 68%;
- 0.15 ± 0.030 l/s, confidence level of 95%;
- 0.15 ± 0.039 l/s, confidence level of 99%;
- 0.15 ± 0.045 l/s, confidence level of 99.7%.

4.7. Spot 7. Mathematical model and program

OBSERVATION & DISCUSSION: The determination of uncertainty requires several calculations. A computer program to solve this task may be useful, to save time and effort.

THEORY: The methodology for the calculation of the uncertainty of flow-rate in the case of repeated measurements is shown in Figure 6.

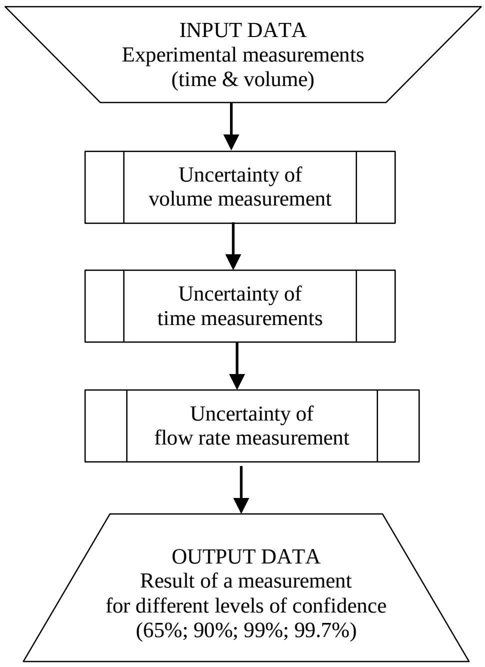


Figure 6. The methodology for calculation of flow-rate uncertainty for repeated measurements

The flow chart contains three main functions, given in distinct flow-charts, for the uncertainty of: volume (Figure 7.), time (Figure 8.) and flow-rate (Figure 9.).

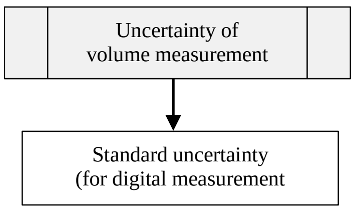


Figure 7. The flow-chart for calculation of volume measurement uncertainty

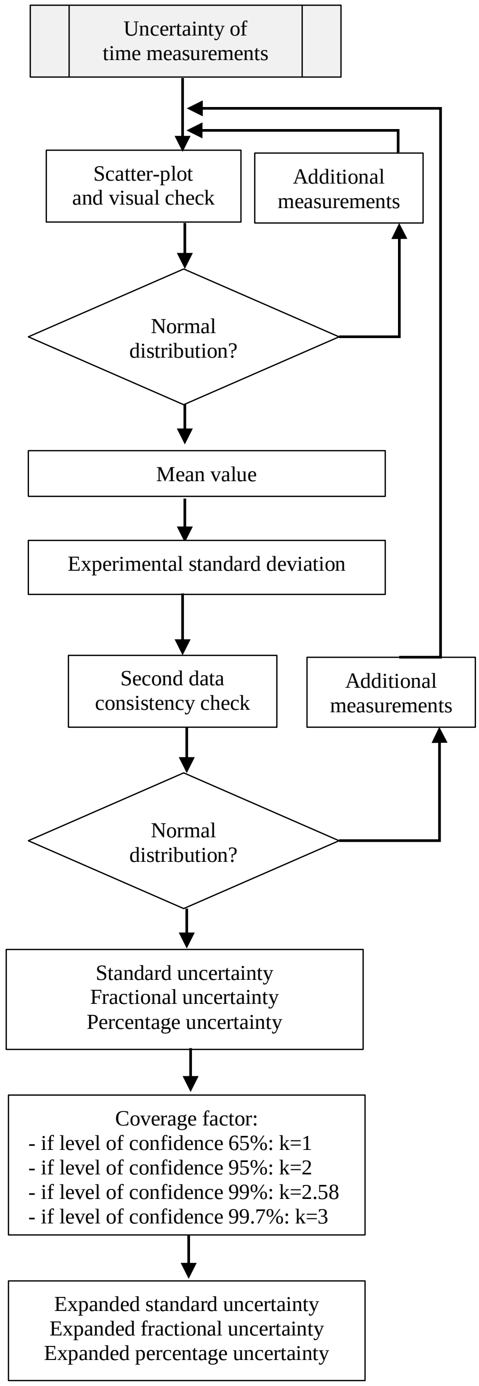


Figure 8. The flow-chart for calculation of time measurements uncertainty

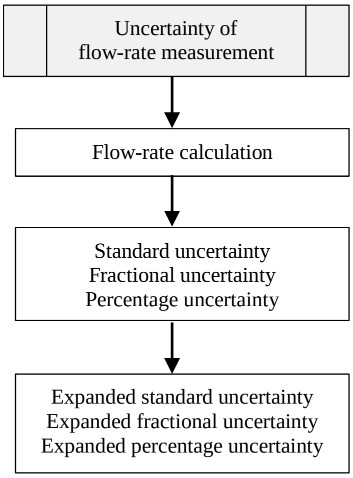


Figure 9. The flow-chart for calculation of flow-rate measurement uncertainty

PROGRAMMING & RESULTS: Students write the mathematical model and the computer program (in Excel or Matlab).

The Matlab function is given in Figure 10.

```
function uncertainty
%Input data
n=10;     % number of experiments
volume=5; % volume measurement
time =[33.466 32.430 33.461 33.269 33.105 33.061
33.870 33.308 33.324 34.107];% time measurements
lc=[68 90 99 99.7]; % levels of confidence
% Volume measurement uncertainty
uV=0.5; % Standard uncertainty (analog measure)
% Time measurements uncertainty
plot(time,1,'b*'); %scatter-plot
mean=0; for i=1:n
    mean=mean+time(i); end;
    mean=mean/n; % Mean time
S=0; for i=1:n
    S=S+(time(i)-mean)^2; end;
sigma=sqrt(S/(n-1)); % Exp. standard deviation
nS1=0;nS2=0;nS3=0;
for i=1:n
if time(i)>(mean-sigma)&&time(i)<(mean+sigma)
 nS1 = nS1+1; end;
if time(i)>(mean-2*sigma)&&time(i)<(mean+2*sigma)
 nS2 = nS2+1; end;
if time(i)>(mean-3*sigma)&&time(i)<(mean+3*sigma)
 nS3 = nS3+1; end;end;
nS1=nS1/n*100;nS2=nS2/n*100;nS3=nS3/n*100;%2test
ut1=sqrt(S/n/(n-1)); % Standard uncertainty
ut2=ut1/mean; % Fractional uncertainty
ut3=ut2*100; % Percentage uncertainty
% Extended uncertainty:
k=[1 2 2.568 3]; %coverage factor
for i=1:4
    uut(i)=ut1*k(i); % Standard uncertainty
    uutrap(i)=ut2*k(i); %Fractional uncertainty
    uutproc(i)=ut3*k(i);%Percentage uncertainty
    end
% Flow-rate uncertainty
Q=volume/mean;
uQ1=Q*sqrt((uV/volume)^2+(ut1/mean)^2);% St.unc.
uQ2=uQ1/Q;    % Fractional uncertainty
uQ3=uQ2*100; % Percentage uncertainty
for i=1:4
    uuQ(i)=uQ1*k(i);    %Standard uncertainty
    uuQrap(i)=uQ2*k(i); %Fractional uncertainty
    uuQproc(i)=uQ3*k(i);%Percentage uncertainty
end
```

Figure 10. Matlab function for flow-rate uncertainty

4.8. Spot 7. Uncertainty standards and further reading

There are two international standards for measurements and uncertainty widely used [16]: VIM (International Vocabulary of Basic and General Terms in Metrology) [8] and GUM (Guide to the Expression of Uncertainty in Measurement) [7]. The presented spotted-subjects cover only a small part of these standards. Recommendations for further reading:

-VIM. International Vocabulary of Metrology - Basic and General Concepts and Associated Terms, Third edition. JCGM 200:2012 (JCGM 200:2008 with minor corrections) [8],

-GUM. Evaluation of measurement data - Guide to the Expression of Uncertainty in Measurement. JCGM 100:2008 (GUM 1995 with minor corrections) [7].

-The NIST Reference on Constants, Units, and Uncertainty [17].

5. Conclusions

As the cognitive structure of the students is changing, the education methods must be adapted to their possibilities, requirements and needs. The main characteristics that bring the method of experimental subject-spotted presented in the paper closer to the characters of the Gen Z students are:

- the splitting of the subject into several independent and simpler issues, which allow an immediate solution,
- the permanent switch between experiments and theory, which allows the shifting of attention from theory to practice.

The accent is on bringing knowledge closer to practice. The deeper study of the problem is left for returns on the subject, after the background is already achieved and other subject-spots can be easily acquired. It is very important to leave some open gates and recommend further reading for continuing the study of the subject, to exclude the wrong impression that everything was told and the subject can be closed.

The application presented in the paper refers to the complex issue of uncertainty of measurement. As the subject is polyvalent and difficult to understand, the splitting into small spots with short experiments offer a good solution that can be used for students. It is an open method, as it permits the easily completion with other subject-spots. There are addressed habits that describe the present Gen Z students, like multi-tasking actions, fast attention shifting, increased distractibility, decreased sustained attention, low information retention and focus on immediate results.

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