EDU0004

Self-Learning Set for Shear Force and Bending Moment Calculation of a Simple Support Beam

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Abstract

This research work was to create a self-learning set for helping learners calculate the shear force and bending moment of a simple support beam under the load. The self-learning set comprised of an aluminum beam with two supports, load cells, interface module, cable, and a personal computer. In the learning process with the self-learning set, learners could understand theory and principle via the lesson content that was provided within the computer-based program, furthermore, the learners could try to put sample loads onto a virtual simple support beam of the self-learning set, then the software computed and displayed the reaction force of each support, the shear force and a bending moment diagram. The aims of this self-learning set were: to help learners to easier understand the lesson, independent learning time, and motivation to learn, also could help the lecturers in order to improve their teaching strategies or managing their classroom activities. After the self-learning set was created, evaluating the quality and the accuracy of the self-learning set was also examined. The results shown that the average answer in error, from a self-learning set, was less than 2% when compared to the calculated results based on the theory. The self-learning set was also used by the sample group of learners, and found to have a high satisfaction rating.

Keywords: Bending moment, Quality, Satisfaction, Self-Learning set, Shear force.

1. Introduction

Nowadays, there are several ways and methods of teaching and learning approaches, such as, active learning [1], e-learning [2], self-directed learning [3], self-expressive learning [4], the main purpose being to improve students' learning outcomes. However, not all learners have been fully satisfied or succeeded with these learning strategies; it still depends on individual learning style [5].

In several engineering programs or related engineering fields, there are some specific basic engineering courses that students must take before going on to other advanced courses in their learning program. Even if it is just a basic engineering course, it has been found that many students could not pass the examination. One reason is that, because it is a pure theory content course, sometime students find it tough to imagine and sketch the image in their mind, finally getting bored, affected the unsatisfied student learning outcomes. Another reason is that the teaching strategies may not help or motivate students to concentrate on the lesson that they are learning. Therefore, the lecturers have always had to look for ways to improve their teaching performance and learning outcomes of the learners, either by improving their teaching techniques or developing teaching aids or media.

In this research, the selected topic is the calculation of shear force and bending moment, and making diagram, under the course of engineering statics. In the author's experience, this is one of the most mistake prone points for students, starting from the calculation of the reaction forces at the beam supports until they make the shear force and bending moment diagram. Therefore, there is a chance to develop a set of learning materials to help learners to improve their learning outcome by extending their learning time, not limited just to the classroom, but also repeatable as often as they need. Furthermore, the self-learning set can be used instead of a teaching assistant; lecturers can manage their teaching strategies to meet their teaching goal. In this research, the self-learning set of shear force and bending moment calculation was created as supporting materials that students or learners can use by themselves for learning the selected topic. The details are as follow.

2. Methodology

As in the introduction above, this research created a set of self-learning for shear force and bending moment calculation that students can use for learning by themselves. This self-learning set comprised of; a scaled virtual simple support beam, personal computer, and computer program, the details are as follows.

2.1 Computer-Based Program and Content

The set of self-learning for shear force and bending moment calculation is comprised of both software and hardware. The software is for the lesson content, also for connecting to the hardware via a computer-based program that the learners can easily access and learn by themselves.

Within this computer-based program, there are three main menus when the user starts the program, the first menu is learning, the second is exercises, and the third is the experiment menu used by the virtual simple support beam when interacting with the computer program.

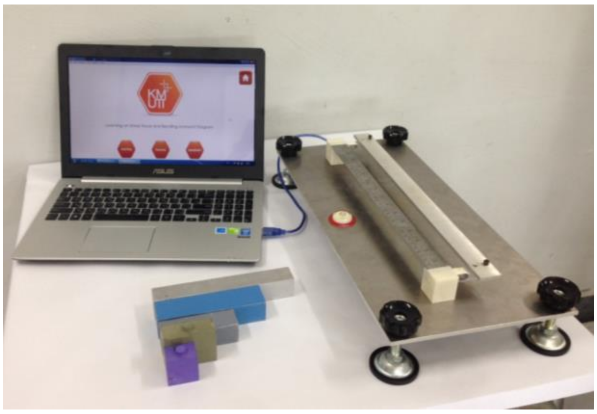


Fig. 1 A self-learning set for learning shear force and bending moment calculation

In the first menu, the basic theories and principles of beams are provided, also examples of how to determine the beam's support forces at the beam supporters, as the external effects, and the shear force and bending moment, as the internal effects, can be found in this menu. The learners can start to learn from this point.

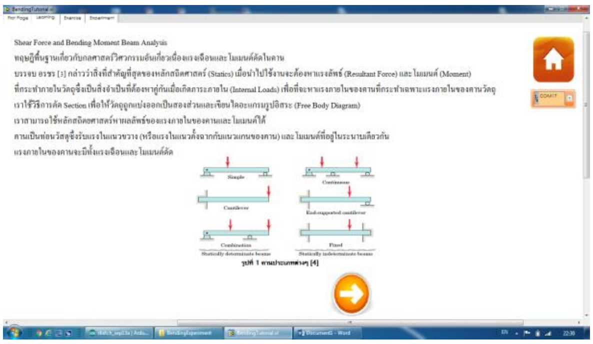


Fig. 2 monitor view of a learning menu of the computer based program

The second menu provides questions and answers related to external and internal effects of beams under load. Each question has four choices of answer; the learner can select only one choice of answer for each question. The purpose of this menu is so that the learners can check their level of understanding. Also the lecturer can check the score of the learner or follow their learning progress.

In the third menu, the learner can connect to the virtual simple support beam via the computer program as shown in the screen shot Fig. 4. Using the virtual simple support beam, the learner can put a single metal box as an external load onto a beam, or a mix of multiple metal boxes for increasing the magnitude of external load onto a beam; the examples of metal boxes can be seen in Fig. 1. When the learner puts a metal box onto a beam, then the computer program that is connected to the virtual simple support beam, will analyze the magnitude of weight and where the metal box is on the beam, and compute how much reaction force there is at each beam supporter, and show the results on the computer screen. Simultaneously, the computer program will generate a shear force and bending moment diagram. With this feature of the self-learning set, the learner can unlimitedly repeat putting various metal boxes onto the beam at any point along the beam's length, and check the reaction forces, shear force and bending moment values, complete with a diagram that is computed by the computer program. These results can also be compared with the results calculated by the learner.

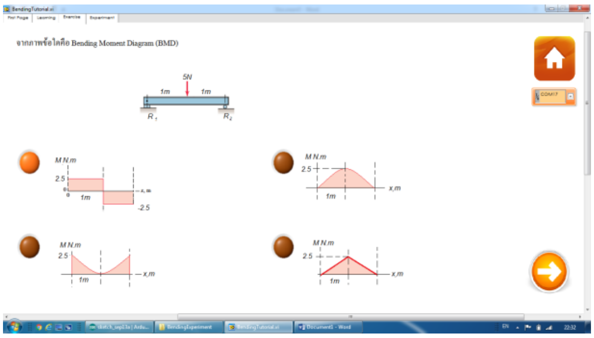


Fig. 3 monitor view of an exercise menu of the computer based program

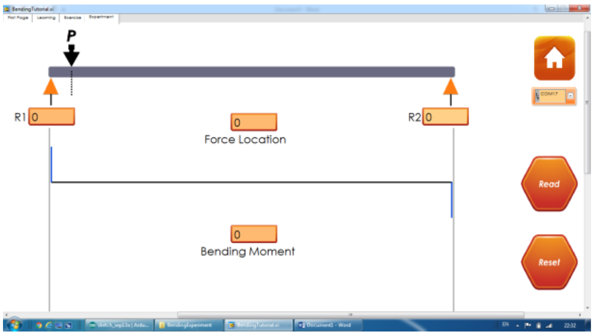


Fig. 4 monitor view of an experiment menu of the computer based program

2.2 Virtual Simple Support Beam

The virtual simple support beam is a part of the self-learning set for shear force and bending moment calculation; the learner can use it via an experiment

EDU0004

menu in the computer program as mentioned previously. A beam was made from aluminum alloy with the dimensions of 400 mm long, 20 mm in width, and 5 mm in height, supported each side by load cell as a beam supporter (see Fig. 6, 7). In this research project, two load cells with 5 kg of measuring capacity each were used, however, it does not mean that the total capacity of measurement per time will be 10 kg, because when the load is not at the middle of a beam, the load acted on a single load cell probably exceeds 5kg if the load is larger than 5 kg. Therefore, the maximum capacity of metal boxes as a load is limited to not larger than 5 kg.

After putting a metal box as a load onto the beam, the two load cells will measure how much the load acted on the beam. In this step each load cell works independently, and sends voltage signals to an interface module. The interface module amplifies the signal, converts analog to digital data and sends to the computer as an input signal for the software program via USB port. The operational software for data processing and programming in this work is NI LabView Academic Site, which is suitable for students to learn and develop later. After receiving the data from an interface module, the software will analyze the amount of load at each beam supporter, the total amount of load, and the position where the load is on the beam. Then, all the results will appear on the computer screen (see example in Fig. 4), also the shear force and bending moment diagram will be drawn.

In the operation, this virtual simple support beam is connected to the computer and the users can do experiments using this virtual simple support beam to simulate the external effect by putting the metal boxes provided onto the beam, then the computer program will analyze and show the results as mentioned above. This interaction between hardware and software can be repeated as often as the user needs. One important thing is that the user must be careful to set to zero the displayed results on the screen each time before using the virtual simple support beam feature.

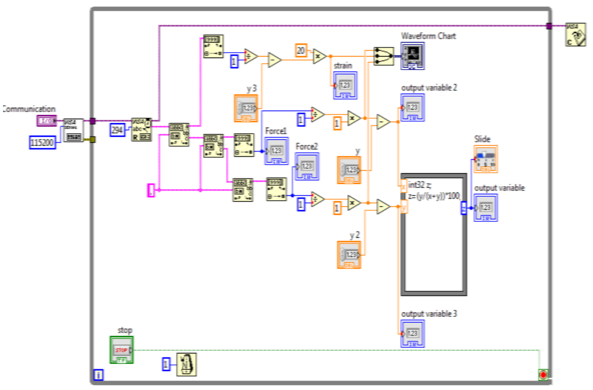


Fig. 5 Software processing diagram of a virtual simple support beam interface with personal computer

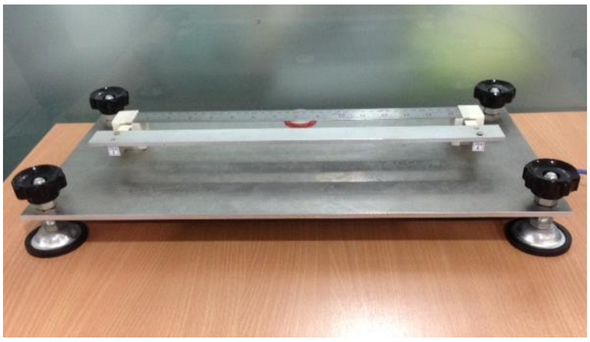


Fig. 6 Virtual simple support beam of a self-learning set for shear force and bending moment calculation

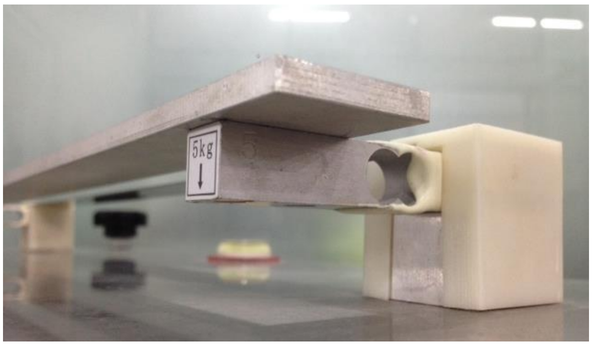


Fig. 7 Load cell as a beam supporter at each side of a virtual simple support beam

2.3 Calibration and Error Analysis

After a self-learning set for shear force and bending moment calculation is made, before using it, it is very important to be sure that the computed values which shown in the program screen are correct and accurate. Therefore, the self-learning set must be calibrated. To calibrate this self-learning set, the virtual simple support beam will be loaded by various metal boxes for simulating various magnitudes of load onto a beam. Then the detected values by load cells will send signals to the computer software, and analyzed to ensure that desired results are shown on the computer screen. These results are now called an experiment value. Another is the theory-based value that was calculated based on the same conditions as the experiment. And then compare the results of both methods. The difference in the results will be shown in the form of percentage of error [6] as

$$\%_{error} = \left| \frac{\#_{experimental} - \#_{theoretical}}{\#_{theoretical}} \right| \times 100 \qquad (1)$$

When $\#_{experimental}$ is a value from the experiment with the self-learning set, and $\#_{theoretical}$ is a calculated value based on theory. In this work the percentage of error is expected to be not larger than 5 %.

2.4 Evaluation

In order to evaluate the learner's satisfaction and how it helps the learner, a self-learning set was brought in to demonstrate how to use it and was used with the sampling group, the details are;

- Sampling and Data Collecting, the sampling group was picked by a simple random sampling method for 30 bachelor students at the Department of Mechanical Technology Education, the Faculty of Industrial Education and Technology, and King Mongkut's University of Technology, Thonburi. These students used the self-learning set and rated their satisfaction follow questions in a satisfaction survey form.

- Statistics evaluation, satisfaction is a feeling, for example, like or dislike, which can be many levels dependent upon each individual. Therefore, to convert the level of feeling into the assigned values, the Likert-Type scale [7] was conducted to interprets student's satisfaction into the number of satisfaction level as

- 1 – Not at all satisfied
- 2 – Slightly satisfied
- 3 – Moderately satisfied
- 4 – Very satisfied
- 5 – Extremely satisfied

From the five satisfaction levels above, we divide it into five ranges of satisfaction levels as following, using mean scores from the samplers

- Mean scores between 1.00 – 1.79 indicates not at all satisfied.
- Mean scores between 1.80 – 2.59 indicate slightly satisfied.
- Mean scores between 2.60 – 3.39 indicate moderately satisfied.
- Mean scores between 3.40 – 4.19 indicate very satisfied.
- Mean scores between 4.20 – 5.00 indicate extremely satisfied.

In order to summarize the satisfaction from 30 samplers, this requires calculating mean scores and standard deviation for data analysis. The mean is calculated using this formula

$$\overline{X} = \frac{\sum x}{N} \qquad (2)$$

Where Σ = Summation
x = Individual data points
N = Sample size (number of data points)

And the standard deviation is the most common measure of variability, measuring the spread of the data set and the relationship of the mean to the rest of the data. The standard deviation is calculated using the following formula

$$S.D. = \sqrt{\frac{\sum (x - M)^2}{N - 1}} \qquad (3)$$

Where Σ = Summation
x = Individual data points
M = Mean of all scores
N = Sample size (number of data points)

However, even though this self-learning set was made with the purpose of improving the student's learning outcome, there was inadequate time within the semester and insufficient groups of students to compare the different learning outcomes. Therefore, the statistical learning outcome evaluation is not evaluated in this stage of the project. Also, there were open-ended questions added within the satisfaction survey form where students could write their comments corresponding to the questions. The questions were;

1. Do you think this self-learning set can help you to get a higher learning outcome? For this question the student will tick "yes" or "no".

2. Why or How? For this question the student will give their opinion.

3. Results

3.1 Error Analysis of a device

Generally, precision and accuracy of measurement devices is not always reliable due to the quality of the instruments that are used with the device. For this work, the device, namely, a virtual simple support beam there also appeared errors in values as shown in Table. 1. In the error analysis, the measured forces by the device were compared to calculations made based on theory.

3.2 Satisfaction of the Users

In this work, users were the samplings from the students who have used the self-learning set for shear force and bending moment calculation. The users were to: access and try to use every function in the computer program; try the experiment menu that has interaction with the virtual simple support beam; observe the interaction between hardware and software; consider how well it worked; how suitable it was; rate their satisfaction on this self-learning set; and finally give their comments and opinions corresponding to the open ended questions. The rated satisfaction on the self-learning set was assessed and shown by mean and standard deviation for each question. The results are shown in Table. 2 and Fig. 8. And the answers of open-ended questions are summarized.

3.3 Open-ended questions

For the additional open-ended questions, the first question, "Do you think this self-learning set can help you to get a higher learning outcome?" 76.67% of students ticked "yes", but the rest, 23.33% of students did not tick "yes" or "no".

For the second question, "Why or How?", it was summarized as; 46.67% of students answered that a self-learning set is a good guide for understanding the lesson, 13.33% of students answered that a self-learning set can stimulate them to have participation in the classroom, 16.67% of students answered other reasons, and the rest 23.33% of students did not give any opinion.

4. Discussions

4.1 Error Analysis of a device

From the error analysis, it was found that the lowest error was 0.031 % (except when there was no load on the opposite side of supporter), and the highest error was 4.768% when considering point-to-point error. And the lowest error was 0.637 %, and the highest error was 1.581% when considered as the average error. Most of the errors (see Table. 1), related to the reaction force at the supporters, the R_1 supporter was always showing a larger force compared to the calculation result. On the other hand, the R_2 supporter was always showing a smaller force compared to the calculation result. This means the device has high precision and repeatability. However, it was still an error. The cause of error could come from

- The quality of the load cells that were used, its accuracy could affect the device's error.
- The placement position of a metal box on a beam, it doesn't have a fixed position for putting a metal box on a beam. Therefore, it is possible the error will occur from position error.

As it was always a larger force at R_1, and a smaller force at R_2, when compared to the calculations, the root cause may come from the length scale on a beam that will always affect the metal box placement position error.

At this stage of the research project, the average error is still smaller than the target at 5%, so it would be acceptable, and could be improved later.

Table. 1 Error analysis of the self-learning set under the same load at different positions on a beam

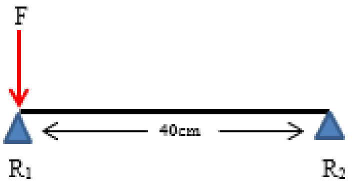
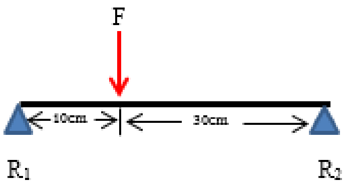
Position of force on a beam	F = 6.377 N		F = 9.369 N		F = 14.225 N	
	Error @ R_1	Error @ R_2	Error @ R_1	Error @ R_2	Error @ R_1	Error @ R_2
	0.003 N 0.047 %	0.000 N 0.000 %	0.008 N 0.085 %	0.000 N 0.000 %	0.025 N 0.176 %	0.000 N 0.000 %
	0.077 N 1.160 %	- 0.076 N 4.768 %	0.142 N 2.21 %	- 0.100 N 4.270 %	0.179 N 1.678 %	- 0.121 N 3.403 %
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Table. 2 Satisfaction level rated by the sampling group of learners

No.	Item	Mean	S.D.	Satisfaction level
1.	Suitable size and dimension	4.02	0.817	Very satisfied
2.	Suitable materials	4.14	0.738	Very satisfied
3.	Durability	3.96	0.876	Very satisfied
4.	Interesting	4.21	0.789	Extremely satisfied
5.	Easy to connect with computer	4.44	0.699	Extremely satisfied
6.	Computer program is easy to use	4.67	0.516	Extremely satisfied
7.	Safety while using	4.12	0.876	Very satisfied
8.	Movability and low maintenance	3.88	1.135	Very satisfied
9.	Motivation to learn	4.29	0.789	Extremely satisfied
10.	Helpful for understanding the lesson	4.4	0.699	Extremely satisfied
Overall		4.17	0.793	Very satisfied

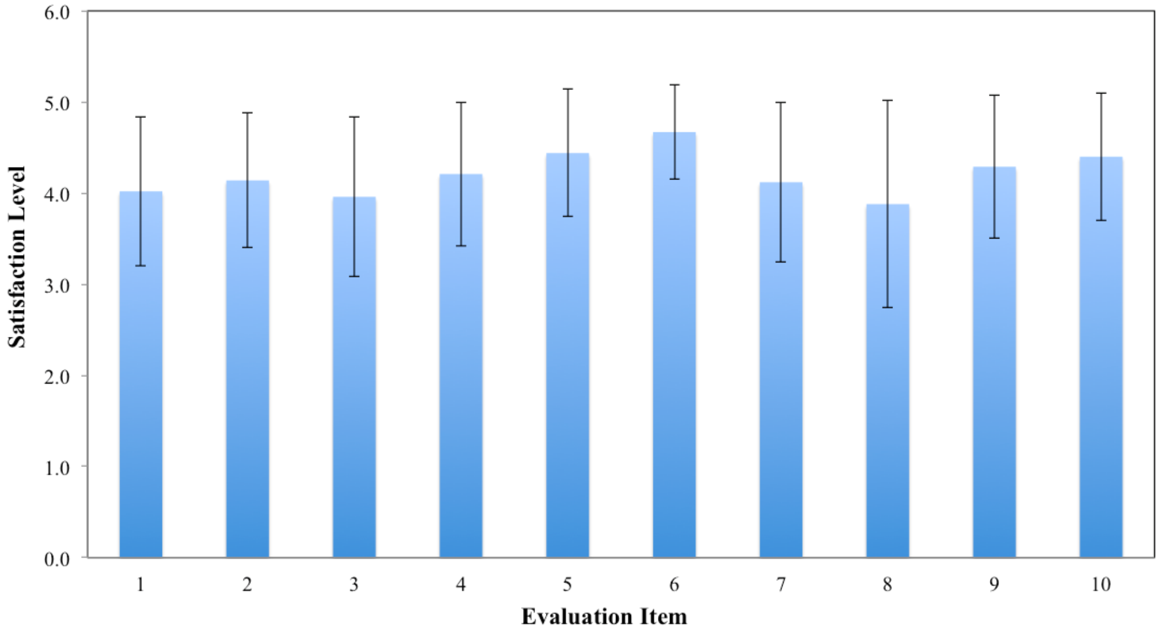

Fig. 8 Satisfaction levels on the self-learning set for shear force and bending moment calculation, with error (standard deviation) bars; the evaluation item corresponds to the item in Table. 2 above.

4.2 Satisfaction

Reviewing Table.2 and Fig. 8; it was found that half of the evaluation items scored extremely satisfied, and the other half got very satisfied, no any item got a lower satisfaction level than "very satisfied", and the results were "very satisfied" overall. In conclusion, it could be shown the strong points and weak points of a self-learning set as follows:

- **Strong points**
  1. Computer program is easy to use; the highest satisfaction ($\overline{X}$ = 4.67).
  2. Easy to connect with computer ($\overline{X}$ = 4.44).
  3. Helpful for understanding the lesson ($\overline{X}$ = 4.40).

This may reflect that the learners prefer learning by themselves, with some learning aids that can help them to understand the lesson or content that they are interested in.

- **Weak points**
  1. Movability and low maintenance ($\overline{X}$ = 3.88).
  2. Durability ($\overline{X}$ = 3.96).
  3. Suitable size and dimension ($\overline{X}$ = 4.02).

This may reflect that our self-learning set does not meet the appropriate size and dimension for movability and durability of the device.

4.3 Open-ended questions

Most of the students were agreed that a self-learning set could help them to improve their learning outcome. However, the quality of our materials with a view to improving the student-learning outcome did not perform as yet. However, the information received at this time, could guide us to improve our materials before using with a real sampling group for evaluation later.

5. Conclusion

This research idea came from the learning and teaching problems inherent in conventional learning and teaching styles, the lecturers are always looking for the new teaching aids to help them teach, also the learners are always trying to find a satisfying learning method whereby they can understand the subject matter easier. This research tried to create new learning aids for learners to learn the given topic by themselves, and because it is made for supporting the lesson under the course of engineering statics, it should, therefore be something that is applied together with engineering and education knowledge to build it. As a result, the self-learning set for shear force and bending moment calculation was created, and has been evaluated on its quality in terms of computation error, and satisfaction levels of the users of this self-learning set, also allowing open-ended questions for evaluation on how this self-learning set can help the learners.

As far as the device's error, the device, namely, virtual simple support beam, still has some points of high error and this is the first priority to improve the quality later.

For the satisfaction, the important data for the researchers to improve on later has already been shown. However, with the ideal upon which the purpose of this research was based, this self-learning set should have the highest satisfaction in motivation to learn and helpfulness for understanding the lesson. But, unexpectedly these were not the highest satisfaction points. And the results could reflect that the learners pay high attention to something that is very easy for them to use or understand, liked they have rated highest satisfaction on the item "Computer program is easy to use"

From the open-ended questions answers, it was shown that the self-learning set could guide them to learn the given lesson by themselves, allows them to have classroom activities and participation. However, the self-learning set still did not evaluate quantitatively in term of how-well it can improve the learning outcomes of the learners, which is needed more sampling groups and time.

6. Acknowledgement

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EDU0004

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