DEVELOPMENT OF NEURAL NETWORK EXPERIMENT USING FOOD TEXTURE ESTIMATION

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Abstract

This paper describes an experiment for students in an electrical and information engineering course in order to learn an application of neural network model. The input to the neural network model is parameters in the load and the sound which occur when a vegetable is probed by an equipment. The output is the numerical value ranged [0,1]. The value means strength level of food texture words such as “munching-ness” or “crunchiness”. The equipment originally has been developed in order to examine textures of the vegetables in our previous study. The equipment mainly consists of an air cylinder, a sharp metal probe, a sound sensor and a load sensor. The probe is attached on the tip of the rod of the air cylinder. The probe is moved down by the cylinder to cut the vegetable. The vegetable is put on the load sensor. The electrical signals in the sound and the load are recorded simultaneously. The signal data is preserved in PC. The proposed experiment is divided into several steps. Firstly, the students have to make about 20 vegetable samples such as a cucumber and a radish. These samples are made in which the students cut the vegetables in the same size by using a knife and a ruler. Secondly, they have to learn the structure and usage of the equipment. Thirdly, they will carry out an experiment to obtain the sound and the load data of the vegetable samples by using the equipment. They have to memorize the temperature, the humidity, the size of the samples, the sampling rate, the range of the amplifiers, the cylinder air pressure and so on. After the data of all the vegetable samples is acquired in the experiment, they must make a program to analyse the acquired data and construct the neural network model to estimate the textures. The training data is numerical value of the textures such as “munching-ness” and “crunchiness”. They have to determine the appropriate value of the texture of the cucumber and the radish by tasting them. After training the neural network model, they should confirm whether the moderate output is obtained when the test sample data is inputted.

Keywords: neural network, food texture, human sensibility, artificial intelligent, soft computing

Introduction

The feedforward artificial neural network model has been employed in many practical problems using the back propagation algorithm proposed by Rumelhart (1986). In recent year, the neural network model is recognized as effective AI technology. Especially the convolutional neural network (CNN) is recognized as the effective method in the image recognition proposed by LeCun (1998). The soft computing including the neural network also has been applied to engineering design which involves human feelings (Nagamachi, 1995). We have realized the texture estimation system (Kato & Wada, 2018) using soft computing such as neural network and fuzzy logic (Zadeh, 1965). This paper proposes an engineering experiment applying typical neural network model to human sensibility such as food texture.

As shown in Fig.1, the vegetable such as a cucumber is cut by the probe of the proposed original equipment. The sound and the load signal are observed by the sensors and the sensed signals are amplified. The amplified signals are fetched and transferred to PC. The parameters in the signal are converted to parameters W1~W5 in the load and F1~F5 in the sound, which are the input of the neural network model. The model outputs the texture level ranged [0,1] of “munching-ness” and “crunchiness”.

Figure 1 The proposed experiment system.

The students are required to perform following tasks.
(a) The students have to make about 20 vegetable samples such as a cucumber and a radish. The samples are made in which the students cut the vegetables in the same size by using a knife and a ruler.
(b) The students have to learn the usage of the equipment such as the air compressor, the air regulator, the air valve, the signal amplifier and the
data acquisition device, in order to accumulate the load and the sound signal data in the **data store** for all vegetable samples. The students have to carry out an experiment to obtain the sound and the load signal data of each sample by using the equipment. The data of each sample is saved in the **data store**. In addition, they have to memorize the temperature, the humidity, the sizes of the samples, the sampling rate, the range of the amplifiers, the cylinder air pressure and so on.

(c) After the data of all vegetable samples is saved in the **data store** in the above experiment, they must make a computer program to analyse the signal data and calculate parameters W1~W5 and F1~F5, which are the input of the neural network model.

(d) The students program the neural network model to estimate the textures. The training data is the numerical value of the textures such as “munching-ness” and “crunchiness”. They have to determine the appropriate value of the texture of the cucumbers and radishes by tasting them. After they implement the training of the neural network model, they should confirm whether the moderate output is obtained when the test sample data is inputted. The test result is accumulated in the **estimation result data store**.

The idea of the proposed experiment is derived from a graduation research in the last year i.e. 2017. We gave a theme of the research to a student who was fifth grade in the Niihama Collage, National Institute of Technology. We taught him the mechanism of the neural network model. He learned the usage of our equipment and engaged in the given study with interest. He carried out the experiment to obtain the data of the vegetables. We conceived of an idea to design the engineering experiment in which the student can experience our research. In the presented paper, the experiment is performed by a teacher in our collage in order to confirm the reproducibility and to show the reliability of our proposed experiment. In following section, the detail in the performed experiment is described.

(a) **Preparation of Vegetable Samples**

We regard the cucumbers and the radishes as food samples. Because these vegetables are easy to be processed in the same size and form. The students have to cut the cucumber using a knife as shown in Figure 2. The cucumbers are cut as long as about 30 [mm]. The diameters are between 24 and 31 [mm]. Twenty cucumber samples are prepared and preserved in the container and stored in the refrigerator. The process of the radish samples is shown in Figure 3. The radish is cut as long as about 30 [mm] and stamped out with the diameter 30 [mm]. The twenty radish samples are prepared and preserved in the container and stored in the refrigerator. Table 1 shows the summary in the samples. The cucumbers are numbered from 1 to 20 and the radishes are numbered from 21 to 40 in this paper. The students have to comprehend the importance to take information of the samples in their note books.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Cucumber</th>
<th>Radish</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length [mm]</td>
<td>approx. 30</td>
<td>approx. 30</td>
</tr>
<tr>
<td>Diameter [mm]</td>
<td>24 – 31</td>
<td>30</td>
</tr>
<tr>
<td>Number</td>
<td>20 (No.1~20)</td>
<td>20 (No.21~40)</td>
</tr>
</tbody>
</table>
(b) Understanding the usage of the equipment and data acquisition

It is assumed that the students use the equipment shown in Figure 4 in order to obtain the data to infer the texture level of the sample. There is the sound sensor on the metal probe and the load sensor under the food sample such as the cucumber as shown in Figure 4. The equipment can measure the sound and the load simultaneously while the sharp metal probe is stabbing the food when the rod of the cylinder moves down. The air pressure is controlled by the hand valve and regulator shown in Figure 4. The students can set the required air pressure of the air cylinder manually using the air regulator.

![Figure 4 The picture of the equipment](image)

The experiment is carried out under the condition shown in Table 2. Figure 5 shows the pictures when the samples are probed. The students should put the sample in an appropriate place so that the centre of the sample is cut with the probe in every trial. The sampling rate is 25[kS/s] and the period is 10 [s].

![Figure 5 The moment when the samples are probed](image)

<table>
<thead>
<tr>
<th>Condition item</th>
<th>Value / Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cylinder air pressure</td>
<td>0.3 [MPa]</td>
</tr>
<tr>
<td>Temperature</td>
<td>27 [deg C]</td>
</tr>
<tr>
<td>Humidity</td>
<td>66 [%]</td>
</tr>
<tr>
<td>Weather</td>
<td>Clouding</td>
</tr>
</tbody>
</table>

Finally, the data of the 20 cucumber samples and the 20 radish samples is obtained in our implementation and preserved in the data store. We should make a manual to use the equipment in the future.

(c) Analysis of the data in the data store and calculate the parameters

Figure 6 shows the result of the cucumber (sample No.1) in the data store. The top graph illustrates the curb of the load with a red line and the sound with a blue line. The middle graph shows signals for 4 [s] time period which is automatically extracted by considering the maximum load point. The start point of the period is when the probe begins to touch the sample. The extraction method is explained in our previous paper (Kato & Wada, 2018).

![Figure 6 The load and the sound of the cucumber (No.1)](image)

It is found that the small sound occurs while the probe starts to cut inside the sample. On the other hand, when the probe cuts off the sample, the loud sound occurs. The bottom graph shows the FFT result of the sound signal which is extracted for 4 [s] time period. The students have to make the program to show the graphs from the obtained data. They have to comprehend the signal processing such as the FFT through the programming.

Figure 7 shows the result of the radish in the data store. It is found that the radish is hard to cut compared with Figure 6. The students will understand that the sound of the cucumber and radish are not same because the FFT results have the different characteristic.
The extracted 4 [s] load curb is divided into five sections as shown in Figure 8. The parameters in the load W1~W5 are calculated as follows.

1. W1 is the average of the load from 0 [s] to 0.8 [s].
2. W2 is the average from 0.8 [s] to 1.6 [s].
3. W3 is the average from 1.6 [s] to 2.4 [s].
4. W4 is the average from 2.4 [s] to 3.2 [s].
5. W5 is the average from 3.2 [s] to 4.0 [s].

The extracted sound data for 4 [s] is converted by the FFT (Fast Fourier Transform). The FFT result between 1[Hz] to 2000[Hz] are divided into five sections as shown in Figure 9. The parameters in the sound F1~F5 are calculated as follows.

1. F1 is the summation from 1 [Hz] to 400 [Hz].
2. F2 is the summation from 400 [Hz] to 800 [Hz].
3. F3 is the summation from 800 [Hz] to 1200 [Hz].
4. F4 is the summation from 1200 [Hz] to 1600 [Hz].
5. F5 is the summation from 1600 [Hz] to 2000 [Hz].

The W and F are the inputs of the neural network model. Table 3 and 4 show the average and STD (Standard Deviation) of W and F of the cucumber and radish samples, respectively. Figure 10 and 11 show the graphs of Table 3. Figure 12 and 13 show the graphs of Table 4.

<table>
<thead>
<tr>
<th>Table 3 Average of W and F in cucumber samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>W1</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td>Average</td>
</tr>
<tr>
<td>STD</td>
</tr>
<tr>
<td>F1</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td>Average</td>
</tr>
<tr>
<td>STD</td>
</tr>
</tbody>
</table>

The parameters W1~W5 and F1~F5 have dispersion as the STD values show. The sizes, the forms and the fibre densities of the samples are slightly different even in the same samples. It is found that the averages of W2 is the highest in the cucumbers among W1~W5.
Table 4 The average of W and F in the radish samples

<table>
<thead>
<tr>
<th></th>
<th>W1</th>
<th>W2</th>
<th>W3</th>
<th>W4</th>
<th>W5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Average</strong></td>
<td>0.714</td>
<td>1.83</td>
<td>2.11</td>
<td>0.692</td>
<td>0.495</td>
</tr>
<tr>
<td><strong>STD</strong></td>
<td>0.212</td>
<td>0.536</td>
<td>0.821</td>
<td>0.927</td>
<td>1.03</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>F1</th>
<th>F2</th>
<th>F3</th>
<th>F4</th>
<th>F5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Average</strong></td>
<td>9.57</td>
<td>1.85</td>
<td>1.09</td>
<td>2.15</td>
<td>0.405</td>
</tr>
<tr>
<td><strong>STD</strong></td>
<td>5.23</td>
<td>0.87</td>
<td>0.584</td>
<td>0.85</td>
<td>0.138</td>
</tr>
</tbody>
</table>

It is found that W3 is the highest in the radishes among W1–W5. The dispersion of F1 is high in both of the cucumber and the radish.

(d) The neural network model for the estimation of the texture of vegetables

The value of the textures “munching-ness” and “crunchiness” of all the samples will be determined by the students who will eat the samples. In this implementation it is assumed that the texture values are given as shown in Table 5.

Table 5 The texture value of all the samples

<table>
<thead>
<tr>
<th>Texture</th>
<th>Cucumber</th>
<th>Radish</th>
</tr>
</thead>
<tbody>
<tr>
<td>Munching-ness</td>
<td>1.0</td>
<td>0.7</td>
</tr>
<tr>
<td>Crunchiness</td>
<td>0.7</td>
<td>1.0</td>
</tr>
<tr>
<td>Sample number</td>
<td>1~20</td>
<td>21~40</td>
</tr>
</tbody>
</table>

The texture “munching” sounds like “boliboli” and “crunchy” sounds like “kalikali.” Since the cucumber has the peel, the cucumber can be munching. On the other hand, the radish is considered crunchier than the cucumber. The neural network model for the estimation of the textures is constructed as shown in Figure 14.

![Figure 14](image)

The model is the typical feedforward neural network. The input layer consists of 10 nodes for W1–W5 and F1–F5, and one bias node. W1–W5 and F1–F5 are normalized in [0, 1]. The hidden layer 1 and 2 consist of 10 nodes and one bias node, respectively. The output layer consists of two nodes expressing the degree [0, 1] of “munching-ness” and “crunchiness”. The transitional function of the hidden layer 1, 2 and output layer are the sigmoid function. The detail is described in the previous paper (Kato & Wada, 2018).

Only one sample out of 40 is selected for testing the trained neural network model. The rest 39 samples are used for training. The training and the test are carried out as follows:

Step 0: \( i \leftarrow 1 \)

Step 1: Select \( i \)-th sample data out of 40 samples

Step 2: Prepare following the 39 train input vectors except \( i \)-th data

\[
X^{(n)}_{\text{train}} = \begin{bmatrix}
W^{(n)}_1 \\
\vdots \\
W^{(n)}_5 \\
F^{(n)}_1 \\
\vdots \\
F^{(n)}_5
\end{bmatrix}
\quad \text{for } n = 1, 2, \ldots, 39.
\]

Step 3: Prepare following the 39 correct output vectors

\[
Y^{(n)}_{\text{train}} = \begin{bmatrix}
y^{(n)}_1 \\
y^{(n)}_2
\end{bmatrix}
\quad \text{for } n = 1, 2, \ldots, 39.
\]

where, when \( n \) is the sample data of cucumber \( y^{(n)}_{\text{train}} = \begin{bmatrix} 1.0 \\ 0.7 \end{bmatrix} \) is assigned, otherwise \( y^{(n)}_{\text{train}} = \begin{bmatrix} 0.7 \\ 1.0 \end{bmatrix} \) is assigned. These values are accordance with Table 5.

Step 4: Initiate the connection weights \( w, v \) and \( u \). Train the neural network model by the back-propagation algorithm. The training process is carried out by adjusting the connection weights \( w, v \) and \( u \) so that \( Y^{(n)}_{\text{train}} \) is outputted when corresponding \( X^{(n)}_{\text{train}} \) is inputted.
There, the iteration to train the network is 30 epochs. It is necessary to observe whether the error declines as the epoch proceeds.

**Step 5:** Input $W_1$–$W_5$ and $F_1$–$F_5$ of $i$-th sample data into the neural network model trained in **Step 4**. The output vector is registered in the *estimation result data store*. When $i = 40$ the routine is completed, otherwise $i ← i + 1$ and go to **Step 1**.

Table 6 shows the average and STD of the *estimation result data store*. Although the sample data not used for training is inputted to the neural network model, the model outputs generally moderate texture values.

Table 6 Summary of the *estimation result data store*

<table>
<thead>
<tr>
<th></th>
<th>Cucumber (No.1–20)</th>
<th>Radish (No.21–40)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean of Munching-ness</td>
<td>0.978</td>
<td>0.736</td>
</tr>
<tr>
<td>STD</td>
<td>0.0579</td>
<td>0.158</td>
</tr>
<tr>
<td>Mean of Crunchiness</td>
<td>0.715</td>
<td>0.948</td>
</tr>
<tr>
<td>STD</td>
<td>0.0873</td>
<td>0.113</td>
</tr>
</tbody>
</table>

Regarding the result of this implementation, it is found that the neural network model estimates the expected textures almost correctly, even though the $W_1$–$W_5$ and $F_1$–$F_5$ have the dispersion. Figure 15 shows the *estimation result data store*. The asterisk shows the estimated texture value for each sample.

Our implementation shows the possibility of the realization of the proposed students’ experiment.

**Result and discussion**

The students can experience various topics from producing the vegetable samples to programing. In the data acquisition task, they have to understand the mechanical structure of the equipment and electrical mechanism of the sensors and amplifiers. In the programing task, they have to make the graphs representing the signal data. They have to learn the FFT. In addition, they will recognize the dispersion among the samples. After the neural network model implementation, they will recognize the flexibility of the neural network model. The model can infer moderate texture value after training.

**Conclusions**

This paper proposed the experiment which includes the sample production, the equipment manipulation, the data acquisition, the sensory test for the food texture, the data analysis and the modelling of the neural network. Through all the experiences, the students will recognize the essential sensibility for the research. In the future, we will realize the proposed student experiment environment by making the manual.

**References**


DEVELOPMENT AND PRACTICE OF AN EXPERIMENTAL KIT FOR
THE “IN-SITU EXPERIMENT” IN ELECTRONIC CIRCUIT RELATED CLASSES

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Abstract

In our Electrical Engineering department, we have been introducing a new engineering education method called “in-situ experiment” into the specialized subjects since 2009. It is an education method based on simple experiments performed in classroom for our students to check and confirm basically physical laws and rules just after learning them. In the electrical engineering, the electrical and electronic circuits are fundamental subjects to learn the wide range of specialized subjects when students advance to the next year. In our department, 1st and 2nd year students learn the electrical circuits including digital circuits in the classes named "Fundamentals to Digital Circuits" for 1st year students and “Basic Electric Circuits” for 2nd year students. In these classes, the students make typical logic circuits by themselves during class to confirm each function and movement of digital devices. In the class of "Basic Electric Circuits" for 2nd year students, they learn for the first time Kirchhoff’s law, a principle of superposition in linear electrical circuits and Thevenin’s theorem through the in-situ experiment. Among them, Thevenin’s theorem is a key theorem to analyze electric circuits but difficult for students to understand. In order to make these theorems easily understandable, we fabricated a small size of variable DC voltage source and a quasi-sine wave generator by using a dry battery. We confirmed the effectiveness of the in-situ experiments through the improvement of the average scores of the examination. We also conducted questionnaire survey about the "in-situ experiment”. As a result, we got many positive opinions on the in-situ experiment from the students. As a further positive aspect, the number of students who repeat the same classes decreased by about half before the introduction of the in-situ experiment for 1st, 2nd and 3rd year students in our department.

Keywords: in-situ experiment, first-year education, digital circuit, electric circuit, Kirchhoff’s law, Thevenin's theorem

Introduction

One of main features of KOSEN (National College of Technology in Japan) education is a specially designed curriculum having specialized subjects which are introduced in an early stage of college year. However, there are some students who cannot follow the classes of the specialized subjects. Such students tend to lose their interests in their specialized subjects and find it difficult to continue to study those specialized subjects. Unfortunately, a few students resulted in leaving the college, which we think is related to some abstract contents of the specialized subjects such as electric circuits.

We propose here a new education method to resolve the above-mentioned problem in the early stage of college year. It is a positive introduction of simple experiment in a classroom for students to check and ensure physical laws and rules just after learning them. We called it “in-situ experiment” and have introduced actively this “in-situ experiment” into the early-stage of our engineering education since 2009. After that time, we have developed two kinds of “experiment kit” to execute the "in-situ experiment " in a classroom. We expect that this kind of the “in-situ experiment” makes it easier for them to understand abstract physical laws or rules.

In this paper, we report introduction of newly developed “in-situ experiments” into introductory classes related to electrical and electronic circuits for 1st year and 2nd year students of the department of electrical engineering and verify their educational effects.

The “in-situ experiment” in the specialized subjects for 1st year students

We introduced “in-situ experiment” into two specialized subject classes for 1st year students. One is a class named “Fundamentals to Electrical Engineering”. Students learn basic contents of electric circuit and electric magnetics in this class. Figure 1 shows a photograph of students who are performing the “in-situ experiment” we introduced. They are measuring physical values of electronic elements in circuit.

In addition, "Fundamentals to Digital Circuits” are also taught in this class to learn logical algebra as well as logic circuits. Figure 2 is another photograph in the same
classroom, in which students are assembling a logic circuit using an IC trainer kit and confirm how to work them. The IC trainer kit has a bread board, switch and LED and it can work with two dry batteries. This kind of "in-situ experiment" is practiced in the class every week during one semester.

Figure 1. Photograph of the class of "Fundamentals to Electrical Engineering". Students are measuring physical values of the electronic elements by a circuit tester.

Figure 2. Photograph of the class of "Fundamentals to Digital Circuits". Students are designing a logic circuit and connecting wires on bread board.

These new in-situ experiments we introduced are effective for 1st year students as introductory specialized classes. We confirmed their effectiveness from the average score. Table 1 shows the average scores of "Fundamentals to Digital Circuits" from 2007 to 2010. The average score gradually increases year after year by the introduction of the in-situ experiment into the class.

<table>
<thead>
<tr>
<th>Years</th>
<th>Average</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>77.3</td>
<td>11.7</td>
</tr>
<tr>
<td>2008</td>
<td>79.2</td>
<td>12.9</td>
</tr>
<tr>
<td>2009</td>
<td>80.8</td>
<td>11.5</td>
</tr>
<tr>
<td>2010</td>
<td>81.3</td>
<td>13.6</td>
</tr>
</tbody>
</table>

Table 1. Final average scores of "Fundamentals to Digital Circuits". We have introduced the "in-situ experiment" from 2008.

Introduction method for the subject of 2nd year students

In the class of “Basic Electric Circuits”, students learn about Kirchhoff's law, a principle of superposition in linear electrical circuits and Thevenin's theorem as fundamental laws in electrical and electrical circuits for the first time. In order to performing the "in-situ experiment" about these law and rules, we developed a small sized variable DC voltage source and a quasi-sine wave generator by using a dry battery, which are suitable for the "in-situ experiments".

In the first semester of the class named "Circuit Foundation", they learn about fundamental laws of DC circuit. Just after learning some fundamental laws, they confirm them through the “in-situ experiment”. For example, students performed practices “Thevenin’s theorem” using the real circuit shown in Figure 3. Through this kind of the “in-situ experiment”, students understand that a circuit including a voltage source surrounded by the dashed line in the left figure is equivalent to a simple voltage source model which include only one voltage source and one internal resistance.

Figure 3. Thevenin's theorem of the direct-current circuit I.

Figure 4 shows the expanded circuit diagram surrounded by the dashed line in Figure 3, and how to measure open-circuit voltage (left circuit) and internal resistance (right circuit) for Thevenin's theorem. For these experiments, we used the new DC voltage source fitting to the “in-situ experiment”. It is a variable DC voltage source with a small size working composing of one small battery. The new variable DC voltage source was operated by an OP Amp to get stable output voltage. The DC voltage more than 3 V is necessary to do the “in-situ experiment”. Therefore, we also used DC-DC converter to increase the voltage from 1.3 to 3.3 V. Figure 5 is a circuit diagram of the simple variable DC voltage source we designed. Chip components were used for the simple variable DC voltage source to arrange them in a small area of the board. One equipment cost is only approximately 1,100 yen.

Figure 4. Thevenin's theorem of the direct-current circuit II.

Figure 5.
In "Basic Electric Circuits" of the second semester, the students learn about the basics of alternating current (AC) circuits and fundamental concepts and laws for AC circuits such as impedance and Ohm's law. We also developed a new “in-situ experiment” for measurement of AC impedance. In this “in-situ experiment”, students build up a circuit which is composed of coil, capacitor and oscillator. For the experiment, we have designed a simple oscillator which works with one battery. Although the designed simple oscillator cannot produce exact sine-wave signal, the simple oscillator is enough to measure AC impedances with an appropriate accuracy for the “in-situ experiment”. The circuit diagram of the simple oscillator is shown in Figure 6. This equipment is composed of only chip devices to be downsized. We fabricated this equipment with approximately 350 yen. Therefore, we could distribute it to each student in the class.

Figure 7 shows the completed circuit boards of the simple variable power supply (red board) and the oscillator (green board). This simple variable power supply can produce voltage range of 0-2.4V by a variable resistance. The simple oscillator produced quasi-sine wave by connecting capacitor and resistor to a battery. An upper limit of the oscillatory frequency is approximately 1.5 kHz. Students measure voltages across each element as well as across two elements in a series circuit comprised of a resistor and a capacitor when applied an appropriate AC voltage. In DC circuit, the whole voltage is simply the sum of voltages across each element, resistor and capacitor. In AC circuit, on the other hand, the whole voltage is not the sum of voltage of each element. Through the “in-situ experiment”, the students can understand difference between DC and AC circuit. Furthermore, the students learn about the phasor representation which explains visually AC circuits with sine wave signal in complex plane. In addition, they also realize that an impedance of the capacitor decreases increasing frequency.

In order to ensure the effectiveness of the “in-situ experiments” for students, we conducted questionnaire at the end of the semester. The results are shown in Figure 9-12. As can be seen in Figure 9, the positive responses from students on the question of "Interests for the electrical engineering" are more than 90%. In Figure 10, the positive responses on the question of "Understanding
of the specialized subjects” are more than 80%. Furthermore, as can be seen in Figure 11, it was found that the students who feel to be able to understand the theorem or rules increases year by year. In Figure 12, approximately more than 70% students answered that they want to do the same number of the “in-situ experiment” at least. From these results, it is shown that the “in-situ experiments” lead to enhancement of their interests and motivations in the field of electrical engineering. However, we think that the contents of the “in-situ experiments” need to be improved continuously.

![Figure 9. The result of question "Interests for the electrical engineering".](image)

![Figure 10. The result of question "Understanding of the specialized subject".](image)

**Results and Discussion**

In our department, the so-called “in-situ experiments” were introduced from 2009. Table 2 shows an average number of students in a class who repeat the same academic year or leave college for 1st, 2nd and 3rd year students in the department of Electrical Engineering. For comparison, the similar average numbers for other departments in our college, Mechanical Engineering, Electronics & Information Engineering, Civil engineering, and Architecture, are also shown in the table. After the introduction of the “in-situ experiments”, the number of students in the department of Electrical Engineering decreases. On the other hand, such kind of decrease is not distinctly seen in other departments in our college. From this result, we can say that the “in-situ experiment” is effective education method for students in the early-stage of engineering education of KOSEN, especially in the department of Electrical Engineering.

![Figure 11. The result of question "Which aspect did you change your mind after doing the in-situ experiments".](image)

![Figure 12. The result of question "How many times do you want to do the in-situ experiment in a class".](image)
Table 2. Average number of student who repeat the same academic grade or leave college.

<table>
<thead>
<tr>
<th></th>
<th>Before introduction</th>
<th>Introduced</th>
</tr>
</thead>
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<tr>
<td><strong>Electrical engineering department</strong></td>
<td></td>
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</tr>
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<td>1st</td>
<td>0.0</td>
<td>0.4</td>
</tr>
<tr>
<td>2nd</td>
<td>1.0</td>
<td>0.5</td>
</tr>
<tr>
<td>3rd</td>
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<td>0.7</td>
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<tr>
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</tr>
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<td>0.2</td>
</tr>
<tr>
<td>2nd</td>
<td>0.9</td>
<td>0.8</td>
</tr>
<tr>
<td>3rd</td>
<td>1.1</td>
<td>1.9</td>
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<td><strong>Grouping of the year</strong></td>
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<td></td>
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<tr>
<td>1st</td>
<td>2007-2008</td>
<td>2010-2014</td>
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<tr>
<td>3rd</td>
<td>2007-2010</td>
<td>2012-2014</td>
</tr>
</tbody>
</table>

Conclusions

The “in-situ experiment” as a new active learning method has been introduced into the department of electrical engineering in our college (NIT, Ishikawa college) since 2009. In addition, we have been improving the education method of the “in-situ experiment” and developed new in-situ experiments in the classes of electrical circuit. For the new in-situ experiments, we developed small sized power supply and oscillator. It was shown that these “in-situ experiment” help students to understand abstract laws or rules in electrical circuits and keep their interests to electrical engineering. As a result, an average number of students who repeat the same academic year or leave college decreased after the introduction of the in-situ experiment. Furthermore, we need to develop this kind of “in-situ experiment” and to share the other college of KOSEN as a new engineering education.

Acknowledgements

We thank our colleagues, Fukami, T., Ohtsubo, S, Yamada, S., Kawai, Y., Higashi, R., Okamoto, M. and Taya, E. for valuable discussions and comments. This project was supported by “Program for Promoting University Education” from Japan Society for the Promotion of Science.

References


USING GAMIFICATION TO ENGAGE STUDENTS FOR EFFECTIVE LEARNING IN
PROGRAMMING

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Abstract

Learning programming is a challenge for many students who have just made the transition from secondary school to the polytechnic education system. They are new to programming, and learning programming can be very demanding, requiring students to put in time and effort to practice. Therefore, in this action research project, we focused on enhancing students’ engagement and motivation to learn programming by introducing Blackboard gamification in the classroom teaching of programming. The participants of this project were Year 1 students from the Diploma in Business Informatics in School of Information Technology, Nanyang Polytechnic studying the Web Application Development (WAD) module. Gamification is the process of game-thinking and using game mechanics to engage users and solve problems. Blackboard gamification consists of pre-determined achievement milestones and rewards; once these milestones are being achieved, students would be rewarded with the corresponding badges and bonus marks. In this project, milestones were pre-created in Blackboard which were tied to the students’ completion of certain tasks or achieving certain grades in their assessments for their WAD module; students were rewarded with badges and bonus marks accordingly once these milestones were being achieved. Thus, this project postulated that gamification is an efficacious tool to enhance students’ engagement and motivation in learning programming, which would result in students’ improved proficiency in programming. The results of this study showed that generally students enjoyed learning and were motivated to improve their programming skills. However, the overall improvement in students’ practical test mean score for the WAD module was statistically insignificant when compared to the previous cohort of students who studied the same module. In conclusion, while the hypothesis was inconclusive with respect to the insignificant improvement in the practical test mean score of the students, students’ engagement and motivation had been enhanced with gamification. Challenges encountered in this study, such as the limitation of Blackboard gamification features, the limited attempts and time constraint given to students to complete the required tasks and the limited bonus marks awarded could be further enhanced to further improve students’ engagement and learning and even their mean score.

Keywords: Gamification, Programming, Engagement, Motivation, Achievement, Reward

Introduction

In the School of Information Technology, the Web Applications Development (WAD) module is a 60 hours core module offered to all Year 1 students enrolled in the Diploma of Business Informatics (DBI). This module introduces students to the concepts of client and server based web application development, including web page design, mark-up languages, scripting languages, and server development technologies. Students learn how to create web pages using HTML and CSS, add hyperlinks and images to the web pages and build dynamic client based applications using JavaScript and are expected to be able to create interactive web sites upon completion of this module.

It has been observed that students generally find this module difficult to master, as they are new to programming. The learning of JavaScript is particularly demanding, as students have to learn the JavaScript syntax and variables, how to call JavaScript functions and how to write JavaScript programming codes that adds interactivity and validation to the web pages. Students often regarded learning programming concepts and complex syntaxes at the same time to be very confusing and challenging and are required to put in much time and effort to complete all practical exercises in order to achieve a minimum level of proficiency in this module. However, some students encounter problems completing the practical exercises and they often give up easily once their programs do not work. The lack of practice then become a vicious cycle as over time, they became less engaged and motivated to put in effort in learning this module.
How can we engage and improve students’ motivation to learn programming? What are some ways to improve their learning of programming? To enhance students’ engagement and motivation to learn programming, Blackboard (a learning Management System) gamification is being introduced in the classroom teaching of this module. Gamification is the process of game-thinking and using game mechanics to engage users and solve problems (Zichermann and Cunningham 2011). Blackboard gamification consists of setting pre-determined achievement milestones and rewards in Blackboard; once these milestones are being achieved, students would be rewarded with the corresponding pre-determined rewards. In this study, milestones such as students’ attaining certain grades in their quizzes or completion of more challenging questions were pre-created in Blackboard, students were then rewarded with Blackboard badges accordingly once these milestones are achieved. By rewarding students upon their achievements, the aim is to increase their engagement and motivation to continue learning, which eventually would be reflected in an overall better academic performance in various assessments for this module.

Thus, the aim of this study is to determine the efficacy of using gamification to enhance students’ engagement and motivation in the learning of programming by introducing the game mechanics of achievement milestones and rewards in classroom teaching. It hypothesizes that gamification is an efficacious tool to enhance students’ engagement and motivation in learning programming, which would result in students’ improved proficiency in programming.

Materials and Methods

In this study, the cohort of 104 DBI students who were enrolled to study the WAD module in Academic Year 2017 S1 took part in this gamification study, forming the experimental group. All students were exposed to gamified elements from week 11 to week 14 of the semester when the JavaScript topic was being taught. This study was designed with 2-tiered challenge to motivate and scaffold students to attempt the more advance programming questions. The concept of scaffold (Bruner 1975) is to provide students with assistance when they are learning new or difficult tasks. This assistance is gradually decreased as students demonstrate task mastery (Larkin 2002). In the first tier challenge, after each lecture from week 11 to 14, students were required to login to Blackboard to complete an online quiz comprising 7 basic questions and 3 intermediate questions on the topic taught during lecture for that week. Students were allowed 2 attempts at each quiz for them to try to score full marks for the quiz. Students were rewarded with a Full Marks Badge in Blackboard if they manage to achieve full marks for the quiz. In the second tier challenge, from week 12 to week 14, students were required to code 1 advance programming feature using JavaScript, and if their codes executed successfully, student would have earned a Special Achievement Badge which translated to 2 bonus marks. The first tier weekly online quiz challenge would provide hints and prompts towards students’ completion of the second tier coding requirements challenge. In this way, scaffolding is provided to support students’ learning to allow them to progress on their own. A maximum of 6 bonus marks could be earned in this second tier challenge, which would then go towards as ‘merit’ marks for their practical test for this module.

In Blackboard, each of the first tier online quiz challenge was setup together with its corresponding completion and full marks badges. Similarly, each of the second tier coding challenge was setup together with its corresponding Special Achievement Badge. Students were able to view all their rewards from the ‘My Achievements’ screen in Blackboard, in this way, students are able to keep track of their rewards earned.

At the end of the semester, all students were also encouraged to respond to a short online survey on the use of gamification in the learning of the module. A scale of 1-5 was used for the Question 1,2 and 3 in the survey with 1 being least motivated/effective and 5 being very motivated/effective. See Table 1 for the survey questions.

Table 1 : Survey Questions

<table>
<thead>
<tr>
<th>Qn</th>
<th>Survey on the Use of Gamification in the Learning of Web Application Development Module</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>How motivated are you towards achieving some or all of the Full Marks Badges?</td>
</tr>
<tr>
<td>2</td>
<td>How motivated are you towards achieving some or all of the Special Achievement Badges?</td>
</tr>
<tr>
<td>3</td>
<td>Overall, how effective are the badges and bonus marks in motivating you to improve your learning for this module?</td>
</tr>
<tr>
<td>4</td>
<td>How do you feel you have benefited from being rewarded with badges and bonus marks?</td>
</tr>
<tr>
<td></td>
<td>• It makes me more focused on doing well in quizzes and assignment.</td>
</tr>
<tr>
<td></td>
<td>• It makes me feel more engaged in my learning.</td>
</tr>
<tr>
<td></td>
<td>• It makes me more motivated to do well in this module</td>
</tr>
<tr>
<td></td>
<td>• I just want the bonus marks.</td>
</tr>
<tr>
<td>5</td>
<td>Overall, I enjoyed learning how to design and develop web sites.</td>
</tr>
<tr>
<td></td>
<td>• Strongly disagree</td>
</tr>
<tr>
<td></td>
<td>• Disagree</td>
</tr>
<tr>
<td></td>
<td>• Neutral</td>
</tr>
<tr>
<td></td>
<td>• Agree</td>
</tr>
<tr>
<td></td>
<td>• Strongly agree</td>
</tr>
<tr>
<td>6</td>
<td>At the end of the module, I am now more motivated to improve my web development skills</td>
</tr>
<tr>
<td></td>
<td>• Strongly disagree</td>
</tr>
<tr>
<td></td>
<td>• Disagree</td>
</tr>
<tr>
<td></td>
<td>• Neutral</td>
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<tr>
<td></td>
<td>• Agree</td>
</tr>
<tr>
<td></td>
<td>• Strongly agree</td>
</tr>
</tbody>
</table>
Results

To examine the effectiveness of gamification in this experiment, the following data were collected and analyzed.

(1) Analysis of number of rewards earned for the experimental group

![Tier 1 Challenge Summary Chart](image1)

As can be seen from Figure 1 above, the percentage of students who attempted each quiz decline gradually from Quiz 1 to 4. It is also noted that the percentage of students who attempted each quiz twice (in order to try to get full marks) also gradually decreased (although there was an increase in the percentage of students who attempted Quiz 3 twice). In addition, the percentage of students who were awarded full marks for each quiz is low, with only quiz 4 having the highest percentage of 45% of students (who attempted at least once) being awarded full marks.

![Tier 2 Challenge Summary Chart](image2)

From Figure 2 above, the percentage of students who attempted the second tier challenge improved over the 3 challenges, with the percentage of students with successful codes improving over the 3 challenges as well.

(2) Analysis of students’ response to questionnaire on motivation and learning attitude towards programming for the experimental group

![Graph 1](image3)

(1) How motivated are you towards achieving some or all of the Full Marks Badges?

![Graph 2](image4)

(2) How motivated are you towards achieving some or all of the Special Achievement Badges?

![Graph 3](image5)

(3) Overall, how effective are the badges and bonus marks in motivating you to improve your learning for this module?

![Graph 4](image6)

(4) How do you feel you have benefited from being rewarded with badges and bonus marks?
Overall, I enjoyed learning how to design and develop web sites.

At the end of the module, I am now more motivated to improve my web development skills.

Figure 3: Survey Responses

As seen from Figure 3 above, from the responses to Questions 1-3, more than 45% of students feel that they are rather motivated to earn the various badges and to improve their learning. However, responses to Question 4 indicate that 35% of the students are really just keen to earn the bonus marks with another 45% of students feeling more focused and motivated to do well. The responses to Questions 5 and 6 indicate that more than half of the students generally enjoyed learning web development in this module and are motivated to improve their skills further.

Analysis and comparison of practical test and final assignment mean score for both experimental and control groups

The practical and assignment mean score of the 2017S1 cohort (experimental group) was compared with the previous 2016S1 cohort (control group) which also studied the same module. As Figure 4 above indicates, there is a slight improvement of 4 marks in the practical test mean score of the experimental group over the control group. Upon conducting a two-tailed, unequal variance t-test, the p-value is found to be 0.128867. Thus we can conclude that the slight improvement of 4 marks is statistically insignificant. In addition, there is no difference in the assignment mean score for both the experimental and control groups.

Analysis and comparison of overall passing rate and mean score for the module for both experimental and control groups

As Figure 5 and Figure 6 above indicate, there is a slight dip in the passing rate and overall mean score of the experimental group which experienced gamification.

Discussion

Gamification originated in the digital media industry and uses game design elements in non-game contexts (Deterding, Dixon, Khaled and Nacke 2011) with the intent of injecting fun, play and passion into tasks and processes (Wood and Reiners 2015). Game elements include game interface design patterns such as badges and leaderboards as well as game mechanics such as time constraint. Gamification applies the motivational properties of games to learning activities in order to integrate the human desire to communicate and share experience.
accomplishment with goal-setting to direct the attention of learners and motivate them to action. (Landers and Callan 2011). For teaching and learning purposes, key learning objectives are used to apply the elements of gamification on activities that would enable participants to infer the rules for the key learning objectives. The learner would envision the activities in a ‘playful’ way where the participation is voluntary and fun, addressing the passion of the learner to intrinsically feel the obligation to achieve the objectives (Groh 2012).

In gamification, achievements represent the objectives and milestones for the learner and is an example of a game mechanic which measures success, achievements are in turn rewarded with badges which represent success. Being recognized for achievement is a core desire of human beings and achievement-recognition mechanics and rewards in gamification attempts to tap into this desire to motivate learners. In teaching and learning, gamification harnesses the motivational power of games and applies it to solve motivational problems in school. Understanding student’s motivation is important to the success of gamification (Zichermann and Cunningham 2011) as the root of gamification is the student whose motivation ultimately drives the outcome.

Deci (1971; 1972) identified two types of motivation: intrinsic and extrinsic motivation. An intrinsically motivated person is one who engages in an activity for the activity itself; intrinsic motivation is important to sustaining interest and ensuring that learning is retained. According to the Self-Determination Theory (Ryan and Deci 2000), people have three innate psychological needs: Competence, Autonomy and Relatedness, and meeting these needs will increase intrinsic motivation. Competence is the ability to function effectively in the environment and evidence that student’s knowledge and skills are increasing is the most important factor for influencing students’ perception of competence and this explains why praise, meeting expectations, challenging activities are intrinsically motivating. In addition, the theory of operant conditioning (Skinner 1963) states that if a reinforcer is delivered after a certain behavior, then the particular behavior will be strengthened. Positive reinforcer such as praise, rewards, positive feedback, recognition and attention will thus increase the chances of the behavior happening again.

Thus, in this Blackboard gamification research study, positive reinforcer such as badges and bonus points were used to reward and recognize students for their achievements and to encourage their continuous engagement and effort to complete the weekly online quizzes and to attempt the more challenging questions. Successful completion of the more challenging questions would be evidence that their competence and skills have improved and this would improve student’s perception of their competence; encourage them to take charge of their own learning and help them uncover their intrinsic motivation to learn programming.

In this study, while the survey responses showed that students are generally motivated to earn badges which translate to bonus marks, however it is noted that most students did not actually attempt to earn these badges as can be seen from the low level of participation in second attempts of quizzes in the first tier challenge and the low level of participation in the second tier challenge. This could indicate that the students need additional incentives to excite them. Perhaps students may need more than 2 attempts to try their hand at achieving full marks for each first tier challenge quiz or perhaps students were not able to find time to attempt each quiz twice. In addition, the bonus marks for the second tier challenge could be too low as well.

While there may be a slight improvement of 4 marks in the practical test for the experimental group over the control group (which is statistically insignificant), this did not result in an overall improvement of mean score for this module for the experimental group. Thus, the results of this study is inconclusive with respect to the insignificant improvement in the practical test mean score of the students. However, students’ engagement and motivation may have been enhanced with gamification as more than half of the students had generally enjoyed learning web development in this module and are motivated to improve their skills further.

Many research studies have been conducted on gamification, its motivation effectiveness and its impact on performance. An analysis of 19 studies on gamification with the aim to identify similarities, differences and patterns and to search for common themes on the effect of gamification on student motivation and performance in post-secondary students was conducted (Lister 2015). Lister’s analysis shows that 12 of the 19 studies reported a positive impact on students’ motivation as a result of gamification and a small percentage (10%) of the studies reported no impact or negative impacts on student motivation. Additionally, some studies reported mixed results with respect to motivation. It was also found that of those studies reporting results related to academic performance, the results are mixed with some reporting improved students’ performance, some reporting lower examination scores or found little evidence of impact either positive or negative on students’ performance. In another study on the effect of the use of gamification on students’ engagement and achievement in a theory based course, it was found that the mean scores of both experimental group (students who participated in the gamified module) and control group (students who participated in the ungamified module) was not statistically significant (Leaning 2015).

Conclusions

In conducting this study, a number of challenges were encountered. Firstly, it was noted that the Blackboard gamification features is limited with the use of badges to reward achievement. Blackboard’s gamification is therefore static in nature and does not mimic the interactivity of a virtual game to excite and engage students.

Secondly, by limiting students to two tries to earn full marks for each first-tier challenge quiz, students may...
deemed it to be almost impossible to score full marks on
 two tries only, thus not many students actually attempted
twice for each quiz.

Thirdly, students may find the questions in the
quizzes and programming challenges too tough, and thus
many students did not actually succeed in earning full
marks for the quizzes or the bonus marks in the
programming challenges.

In conclusion, while the hypothesis was
inconclusive with respect to the insignificant
improvement in the practical test mean score of the
students, students’ engagement and motivation had been
enhanced with gamification. Challenges encountered in
this study, such as the limitation of Blackboard
gamification features, the limited attempts and time
constraint given to students to complete the required
tasks and the limited bonus marks awarded could be
further enhanced to further improve students’
engagement and learning and even their mean score. A
few ways to improve this study includes: (a) Using a
gamification tool which has more interactivity and
exciting features to engage students in learning; (b)
Allowing students more tries or even unlimited tries at
scoring full marks for each first-tier challenge quiz; (c)
Simplifying the questions in the first-tier challenge
quizzes and second-tier programming challenge to
encourage students’ participation and learning; and (d)
Awarding more significant bonus marks to motivate
students.

References


EFFECT OF SECURITY EDUCATION USING GAMIFICATION

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Abstract

It's the important problem in which a cyberattack cooperates with increasing industry closely to bring the human resources who could excel OT security up. The educational effect in the multiple practice and a problem of KIPS based on Gamification theory were considered. More than one performance contributed to the simple educational effect as a result of the experiment, and some things knew a possibility of the affirmative skill move, but KOSEN where the educational contents which can close a gap of more than one practice are needed has the big mission which renews a curriculum of a practice base all the time.

Keywords: security education, gamification theory, operational technology, ICT

Introduction

The cyberattack of industrial equipment is getting really hot in the industry. Japan's National Institute of Technology (KOSEN) has produced many high-quality industrial engineers in the industry. Last year, we started a cyber security education project and developed an educational system faced with the threat of cyber attack. The fact that KOSEN's students have security skills and knowledge leads to strengthening of cyber security in the field of OT (Operational Technology), so that students can contribute to the industry. Although we have promoted ICT security education using our own educational content, we believe that it is not easy to learn OT security at that time, cybersecurity developed by ourselves. Since many OT security can be learned by actual operation, there is an aspect that it is difficult to obtain the expected educational effect without actual industrial equipment and environment.

KIPS (Kaspersky Interactive Protection Simulation), which has developed by Kaspersky Lab, is the board game using Gamification Theory that we can experience the cyber security practice and will be possible to carry out actual practice by simulating realistic scenarios. In our security educational project, we are advancing the education using KIPS, and examined the relationship between the educational effect using the security contents we developed and the effect using KIPS [1].

It was possible to confirm the difference between to consider the security educational effect which practiced the “Enterprise scenario (Corporate version)” which is KIPS where we are toward ICT security and the “Plant scenario (Water Plant version)” which is KIPS where we are toward OT security and practice a ICT security skill and to practice a OT security skill there. we got the very useful knowledge to consider future's educational policy for the technical college which produces human resources to the industrial world.

The industrial world tries to practice KIPS more than one times targeted for the technical college rawness which acquires a basis of the engineer who can play an active part in such flow this time. When the effect of practicing KIPS more than one times is admitted, the framework to take in during educational policy and excrete stronger human resources effectively can be strengthened. The relation between the skill of OT security and the ICT security skill is also considered in more than one times of implementation. Consideration on this relation will be something to grope after a possibility of the skill transfer with effective OT security and ICT security, and we contribute to improvement of future's educational practice as expected.

Gamification Theory and KIPS

We describe two topics that support the fundamental direction of practice of education using the contents applying the gamification theory which is essentials of our investigation.

A. Gamification Theory

The definition of Gamification has been used as "the use of game-play mechanics for non-game applications" [2] and it is used in many areas such as education, business and medicine. One of the important features of learning by using Gamification or Game-Based Learning is that students actively learn problems and take solutions by facing problems. Problem solving with gamification is also noted to be an important benefit of using games in education [3, 4]. A problem-solving mechanism built with a game-based strategy enables both knowledge acquisition and its application throughout the learning process.
B. KIPS (Kaspersky Industrial Protection Simulation)

KIPS is the cyber security practice by team battle which designed to enhance analytical skill about problems on the cyber security and the risk about latest computer system in operation [5, 6]. Educational targets are executive managers including business managers, departmental managers and information security administrators.

The purpose of KIPS is that to prevent the profit maximally and to preserve the trust during exposure to a series of unexpected cyber threats. The aiming is that to develop and run the cyber defence tactics by selecting best suited plan out of cyber security countermeasure prepared preliminarily (see Figure 1).

(1) Completing in a short time (two hours) while concentrating and having fun in the form of a game
(2) Building up cooperativeness crossover the organization by teamwork
(3) Train upping the autonomy and analytic skill by re-experiencing realistic security events

Practical Procedure and Results

KOSEN students who belong Dept. of Electrical and Electronic Engineering practiced KIPS. They played it total four times. First they played the Water Plant version (see Figure 2) of KIPS twice and then played the Corporation version (see Figure 3) of KIPS twice. Concretely, they played the Water Plant version again after three days of first playing the Water Plant version. And they played the Corporate version of KIPS after four days of second playing of the Water Plant version and then they played the Corporate version again after seven days of first playing the Corporate version.

Figure 2 Water Plant version of KIPS

Figure 3 Corporation version of KIPS

We can confirm the effect of embeddedness of OT security skill and knowledge on multiple playing by examining the score of first playing the Water Plant version of KIPS twice. And we can examine the possibility of skill transfer between OT security and ICT.
security which have different fundamental by examining to compare the score of second play of the Water Plant version with the score of first play of the Corporation version (that is third playing as a whole). Finally, we can also confirm the effect of embeddedness of ICT security (this is the point which is not OT security, that is the ICT security) skill and knowledge on multiple playing by comparing the score of first playing the Corporation version of KIPS twice (the third and fourth playing as a whole) as is the case with examining on twice playing of the Water Plant version.

A. The results of first and second playings of the Water Plant version of KIPS

Figure 4 shows both score of first playing of the Water Plant version and second playing of the one on the scatter diagram. These scores have already standardized, and we said here that subsequent scores were standardized, too. As this result, we can confirm that second score is higher than first one significantly (tow-tailed t-test, \( p < 0.05 \)) and multiple playing makes the effect of certainly embeddedness of skill which they learned (a result of decorrelation test shows that coefficient of correlation had comparatively strong correlation with significant).

\[
\begin{align*}
N &= 29 \\
r &= 0.44 \ (p < 0.05)
\end{align*}
\]

![Figure 4 Scatter diagram of the scores about first and second playing the Water Plant version](image)

B. The result of second playing of the Water Plant version of KIPS and first playing of the Corporation version of KIPS

Figure 5 shows the scatter diagram between the score of second playing of the Water Plant version of KIPS and the score of first playing of the Corporation version of KIPS (which was third playing of KIPS as a whole). We didn’t compare the magnitude relationship between both scores here because they are different version, so we can’t compare simply. The point of view is that weather the skill and knowledge which they learned from playing the Water Plant version can transfer to playing the Corporation version, and then we confirmed the possibility that the result has the effect (a result of decorrelation test shows that coefficient of correlation had weak correlation with significant). However, the factor resulting from this transfer is wide-ranging, so we can only say that that possibility was suggested.

\[
\begin{align*}
N &= 34 \\
r &= 0.36 \ (p < 0.05)
\end{align*}
\]

![Figure 5 Scatter diagram of the scores about second playing the Water Plant version and first playing the Corporate version](image)

C. The result of third and fourth playing of the Corporation version of KIPS

Figure 6 shows both score of first playing (third playing as a whole) of the Corporation version and second playing (fourth playing as a whole) of the one on the scatter diagram. It is peculiar to which we can’t recognize the positive correlation and we can find negative correlation with no significant although the score of second playing is higher than first playing in totality differ from the comparison of Water Plant versions (a result of decorrelation test shows that coefficient of correlation had on significant). This result showed that a lot of reversal case on which the score of second playing is simply higher than the first playing occurred, and that result makes we can’t simply confirm the effect of multiple playing.

These results show that the possibility of the difference of difficulty between the versions on KIPS and the possibility that is different from simple effect that playing number of times influenced the score on the educational effect concerning operational skill and the skill based on knowledge about OT security and ICT security. This result was the important findings while we examine the educational effect and concept in the future. That is, we can suggest the possibility that we need the educational contents which can complement effectively between the multiple playing.
Conclusions

To produce human resources who are good at OT security is important task for KOSEN which is closely cooperation with the industry on which faces increasing cyber-attacks. To incorporate the educational effect using Gamification theory which KIPS has can contribute to accomplishment of original goal on which we have operated our (KOSEN) original security education. In this time, we examined the effect and issues on multiple practicing of KIPS while we advance a series of research to examine the security educational effect using KIPS. Multiple playing made that we can confirm simple positive effect on our practicing the version which has domain of OT security skill mainly. Moreover, we can find that the possibility which OT security skill can transfer to ICT security skill. However, we can’t confirm simple embeddedness of security skill and knowledge by multiple playing while we practiced the version which has domain of ICT security skill mainly. This result showed the needs of educational contents which can complement effectively the gap of multiple playing, and we obtain a great future works to develop such some effective educational contents and to measure that effect at the same time.

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FOSTERING ‘PROFESSIONAL LEADERS’ WITH INTERNATIONAL COMPETENCY THROUGH THE ‘GECEP’: AN ATTEMPT BY THE NATIONAL INSTITUTE OF TECHNOLOGY, NARA COLLEGE

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Abstract

The National Institute of Technology, Nara College, which is the only institution for higher-education in the field of engineering in Nara Prefecture, Japan, is required to foster ‘professional leaders’ with international competency. For this purpose, Nara College launched its Global Education Center (GEC) in April 2017. Further, this organizational reformation attempts to respond to the growing local demand for “global engineers”. In this 21st-century society, concepts like “diversity and inclusion” have important implications; moreover, social mobility is increasing at a fast rate. Consequently, the work environment is undergoing extensive changes. Modern workplaces encourage an environment that fosters diversity and inclusion and enable individuals from various backgrounds and with different identities to collaborate on creating innovative solutions. In this context, the GEC was inaugurated as a central body to promote global education and initiate the expansion of a global network in Nara College. In addition, the GEC developed the Global Engineering Collaborative Education Program (GECEP) for nurturing engineers with a global perspective. The special educational program GECEP offers students special courses to acquire the fundamental skills that are required for working in a global environment. The GECEP consists of two (basic and advanced) courses and sets down three basic skills for a global engineer (“good English communication skills”, “cross-cultural understanding”, and “global communication skills in a specialized field”). In addition, this program targets the development of Solution, Publication, Identity, and Collaboration skills in students by enabling them to experience collaborative project work with foreign students coming from diverse cultural backgrounds. We intend to give a presentation on our efforts for promoting global education, achievements, challenges, and future endeavors toward the development of a local knowledge base of global standards.

Keywords: global education, global engineer, cross-cultural understanding, student exchange, active learning

1. Introduction

As social mobility has increased from globalization, the demand for “global engineers” who can freely communicate with people from various cultural backgrounds and build trusting relationships is growing. As the movement of global human-resources expands, manufacturing that had previously been handled by highly homogeneous groups has been forced to change. The National Institute of Technology, Nara College, launched its Global Education Center (GEC) in April 2017, with the aim of fostering global engineers and promoting global education at our school, premised on the notion that these activities are an important educational mission in today’s society. The GEC is a central organization of global education at the National Institute of Technology, Nara College, which was newly established through the integration of three committees on international exchange, English education, and international student guidance. The steering committee includes faculties elected by each of the five-departments, and it is a central body that promotes global engineer training in Nara College. Today, under the GEC’s initiative, we are collaborating with overseas institutes, especially in the Asian region, and neighboring universities in Nara Prefecture, to promote and expand overseas student dispatch and the overseas student acceptance program. Also, the GEC are overseeing the operation of a special education program. The programs related to global education that are developed under the leadership of the GEC are positioned as one of several significant attempts toward the specialization of education at Nara College, similar to initiatives related to training for “female engineers”. Here, we report on various activities related to training global engineers that have been undertaken by Nara College through the “Global Engineering Collaborative Education Program”.
2. Contents of GECEP

The “Global Engineering Collaborative Education Program” (GECEP) is a special extracurricular education program conducted by the Global Education Center to train global engineers. The program has established the cultivation of “global professional leaders” as an educational goal. In this program, we set down three basic skills required for global engineers as follows: A. “good English communication skills”, B. “cross-cultural understanding”, and C. “global communication skills in a specialized field”. From that point on, we support the development of four specific skills from a global perspective: Solution; ability to solve problems, Publication; ability to transmit research results, Identity; identity and originality, Collaboration; collaborative research and work ability (SPIC). We aim to train professional leaders who can lead innovation in the international community. To achieve this objective, we established the GECEP Basic Program for the five-year basic course students and the GECEP Advanced Program for the advanced course students. Because it is a program aimed at nurturing global professional leaders who embody the above four abilities, students are required to participate in exchange programs with overseas institutions (e.g. participation in overseas training programs), or, for students in advanced courses, to give presentations at international conferences. Also, students are required to take special courses to improve their global SPIC skills. The program started in April this year. Currently, twenty first graders are registered in the Basic Program, and nine advanced course students are registered in the Advanced Program.

3. Achievement goals and subject composition of GECEP

The goal of each of the three basic skills is as follows. First, with regard to “good English communication skills”, we aim for students to achieve the following goals by the time they complete the program.

(Basic Program)
A-a: You can generally understand the flow of speech and discuss about familiar topics.
A-b: You can read and understand English sentences about familiar topics without using a dictionary.
A-c: You can actively participate in conversations about familiar topics and express your own ideas based on your interests and experiences.
A-d: You can give an English presentation while referring to prepared documents in advance.

(Advanced Program)
A-e: You can understand the speaker’s intention about the topics of contemporary society and specialized fields spoken at natural speed.
A-f: You can read necessary information and arguments from papers and materials in your specialty field.
A-g: You can participate in a conversation on a wide range of topics, and can logically express your own ideas.

A-h: You can give an English presentation based on the manuscript, and also respond to questions to some extent.
A-i: You can write an English essay according to the logical order of your specialty field and areas of interest.

Next, with regard to “cross-cultural understanding”, we assume that “attitude”, “knowledge”, “skills” are three key components in a person’s ability to nurture an understanding of different cultures. Students are required to achieve the following goals.

(Basic Program)
B-a: Attitudes: Attitudes such as “susceptibility to culture”, “tolerance to ambiguity”, “respect for different things” are concerned.
B-b: Knowledge: You can understand and explain the basic aspects of “social product and lifestyle”, “religious beliefs”, “sense of values”, and “attitude” in Japan and foreign countries.
B-c: Skills: You can interpret different cultures in relation to your culture, and analyze the values of unknown cultures and have the ability to accept them.

(Advanced Program)
B-d: You can practice the above three components in nurturing an understanding of different cultures and exchange opinions with others from a global perspective.

Finally, with regard to “global communication skills in a specialized field”, we aim for students to achieve the following goals at the end of the course.

(Basic Program)
C-a: You have basic knowledge on mathematics and the natural sciences, and you can apply them to solving problems in your specialty fields.
C-b: In order to solve the problem of your specialized engineering field, you can use the knowledge of the specialized field. You can also solve the problem related to multiple technical fields by understanding the principles in your own field of specialization and applying them to the resolution of problems.
C-c: By using technical terms, mathematical formulas, units etc., you can freely conduct basic communication in English related to your specialized field.
C-d: You can make brief oral presentations in English, and you can also provide a summary of research in English, which consists of hundreds of words.
C-e: You can understand the importance of subjective actions and actively exert your own ability to improve the situation in your surroundings.

(Advanced Program)
C-f: You can combine various types of knowledge related to specialized engineering to tackle issues and consider the influence of that knowledge on society.
C-g: You can make oral presentations in English about your subject area and answer questions, and you can also write an English essay of a few pages.
C-h: You can collate your position with your surrounding situation in more diverse environments and promote work by taking subjective actions.

In order to achieve the above objectives, GECEP provides the following extracurricular subjects.

(Basic Program)
- English Active learning I, II: self-learning through e-learning (Relevant goals: A-a, -b, -c, -d)
- Global Communication: Project-type learning, presentations, and discussion in English (A-a, -b, -c, -d)
- Cross-Cultural Exchange: Participation in short-term overseas students’ acceptance program, Presentation at the report meeting (B-a, -b, -c)
- Overseas Training: Participation in overseas dispatch programs (assumed that exchanges are made in languages other than Japanese)
  Length must exceed 5 days - 30 hours (equivalent to the hours entitled in 15 classes) or more. (B-a, -b, -c, C-e)
- Global Challenge: Participation in the GEC organized events or seminars
  The GEC provides students with 15 opportunities for practice to audit English presentations or lectures. (A-a, -b, -c, B-b, -c, C-b)
- Global Engineer Skills: Lectures and exercises for developing English proficiency in specialized fields (e.g. reading of scientific technical papers and equipment manuals) (C-c, -d)

(Advanced Program)
- Advanced Global Communication: Project-type learning, presentations and discussions in English (Relevant goals: A-e, -f, -g, -h, -i)
- Advanced Global Engineer Skills: Lectures and exercises for English language proficiency training in specialized fields (e.g. Reading English tech-scientific texts, writing short letters in English on special research) (C-f, -g)
- Overseas Internship: Participation in educational programs related to specialized fields for over 10 days - 80 hours (equivalent to the hours entitled in 40 classes) at overseas polytechnic, university etc.
  Presentation at the report meeting (B-d, C-h)
- Advanced Global Challenge: Preparation for presentation in English at the international conference and learning about basic presentation etiquette
  Presentation at the international conference is required as a condition for credit completion. (A-f, -g, -h, B-d, C-g)

To complete the Basic Program, students must complete all credits of courses provided in the Basic Program and maintain the average value of JASSO-GPA, which requires first to fifth graders to achieve 2.3 or higher for regular curriculum. For the Advanced Program, students are required to complete all courses (other than elective compulsory courses) provided in the program and achieve an average score 80 or more in all courses taken as part of the regular curriculum. In addition, as a measure to ensure that students are able to give priority to the achievement of learning goals in the regular curriculum, conditions for continuation of the program are established. In the Basic Program, it is a condition for continuation in the program that the total average score of the grades from the regular curriculum, including elective subjects, is 70 points or more. Therefore, if the total average points at the conclusion of the grade are less than 70 points, students will not be able to enroll in that following year’s program. However, for a situation in which the total average of the grade results is 70 points or higher in the following year or after, students can resume their participation in the program in the following year.

4. Examples of educational practice

I would like to introduce the contents of ‘cross-cultural exchange’, which is one of the GECEP subjects. These are activities of the short-term overseas students’ acceptance program that were undertaken before the establishment of the Global Education Center. This program became a new elective subject in Nara College this year. Now, all regular course students are able to participate in the program as one of their elective subjects. Here, we will report on the activities and accompanying aims to be carried out within the course, focusing on international exchange activities conducted in March 2018. The course was held from December to April.

Lesson 1: Course guidance
Lesson 2-4: Special lectures and workshops
Lesson 5-9: Preparation activities
Lesson 10-13: Acceptance activities
Lesson 14: Preparation for report meeting
Lesson 15: Presentation at Report meeting

Participating students began preparation activities before the arrival of Singaporean students. This time, the meeting was held about once a week beginning 2 months ago and preparations were initiated. In preparatory activities, it is becoming standardized to work on a group basis. We created three groups to introduce Japanese culture, the school profile, campus life, and to play ice breaking games. We conducted rehearsals in advance and discussed opinions among students to improve the contents. A faculty member of the English department also participated in this rehearsal. The English teacher provided opportunities for students to receive guidance and advice on technical aspects, such as whether words are correctly pronounced and whether speakers are aware of audiences’ attention. As the activity became an elective subject as ‘cross-cultural exchange’, we held a ‘cross-cultural understanding workshop’ as a part of the lecture on the subject. In the workshop held last December, two international students studying in their
five-year regular course in Nara College gave presentations about their country (Mongolia, Malaysia), and two teachers in charge of the course also lectured on their respective specialized areas (Thailand and India). The workshop was held with the aim of learning about foreign cultures and society and providing students with the opportunity to acquire a wide range of cultural knowledge that we believe is necessary for global engineers. Also, we intended to provide an opportunity to students, other than classmates and dormitory students, to build friendships with international students.

During the exchange program, it is becoming a standard to conduct campus tours in addition to presentations and games by students. On the campus tour, visiting students tour each department and facilities of our school and learn more about the characteristics of education. The primary objective of this activity is to prepare English manuscripts to introduce Nara College to visitors. However, it seems that this leads to rediscovering the charm of the school for our students at the same time. Apart from activities in school, the program includes companies and factory tours in Nara and neighboring prefectures, as well as visits to cultural heritage sites. These activities are aimed at giving overseas students the opportunity to learn about Japan’s technical capabilities, skilled technologies, and the temperament of Japanese engineers, who provide support. Furthermore, we aim for them to discover “Japanese sensibility” which is part of the tradition of Japanese culture. Conversely, it is expected that Japanese students will also be able to rediscover the cultures and traditions that should give them a sense of pride, and their own Japanese sensibility, by conducting cultural visits with overseas students.

In the exchange activities with Singaporean students that we have had so far, an understanding of different cultures and intercultural exchange are central to the program. In another program, the Hong Kong IVE student acceptance program, which started in 2016, project work is included which is not part of the winter program. This is a new initiative to encourage Japanese and overseas students to acquire more practical English communication skills through collaborative work during which they use English. In the past two programs, we held a workshop on 'Robotics and Disaster' and 'How to take action for environmental conservation'.

5. Reflection

By actively participating in acceptance activities at an earlier age and in a lower grade in school, students seem to be able to overcome their sense of resistance towards endeavoring communication using English through exchanges with overseas people who cannot speak Japanese at all. Among faculty members who have been mainly involved in the international exchange activities of our school, it seems that one idea that is shared in common is to encourage students with abundant experiences related to international exchange to participate in the overseas dispatch program. Meanwhile, a lot of students have decided to participate in acceptance activities considering participating in the dispatch program in the future. Participation in acceptance activities is a precious opportunity in which students can practice their English communication skills using the knowledge of English they have learned in the classroom. Although problems can be observed in terms of English ability, at the same time, we observed that students developed the ability to actively use English to communicate without being afraid of overseas students, as their friendships with overseas students deepened. Also, through the activities, students could notice that there is a problem with their lack of English vocabulary and listening skills. It seemed that their recognition of this fact subsequently led to the motivation for English learning.

We also provide opportunities for participants to talk about their activities for other students and write activity reports to be posted on the website of the Global Education Center to send their experiences to the outside. It is expected that international exchange activities will be acknowledged by many of those inside and outside of the school and that the participation of the students will become more active, through which global education will come to be recognized as one of Nara College’s defining characteristics.

Notes
1. Training of engineers who can be active globally is regarded as an important issue for the entire National Institute of Technology as mentioned in its third mid-term targets. (http://www.kosen-k.go.jp/disclosure.html#mokuhyo_keikaku)
2. For these three components, we refer to Byram’s model on “Intercultural Communicative Competence” (Byram 1997).
3. Regarding Jasso-GPA, see below.

JASSO-GPA Formula
\[ \frac{\text{Total Number of Registered Credits}}{\text{GP=Grade Point}} \]

<table>
<thead>
<tr>
<th>GP</th>
<th>Grade Point</th>
<th>Correspondence table between the end of the school year scores and JASSO-GPA point</th>
</tr>
</thead>
<tbody>
<tr>
<td>100~80</td>
<td>Excellent</td>
<td>Good</td>
</tr>
<tr>
<td>79~65</td>
<td>79~65</td>
<td>64~60</td>
</tr>
</tbody>
</table>

Acknowledgements

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References

INTRODUCING ARTIFICIAL INTELLIGENCE FOR CYBERSECURITY THROUGH PROJECT-BASED LEARNING

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Abstract

Artificial intelligence (AI) has gained prominence over the last few years. The field of AI is not new; in fact it has its roots in 1956. It soon became apparent to the researchers that they had underestimated the difficulty of creating intelligent programs given the limitations of computer hardware at the time. Fast forwarding to 2018, the computing hardware available has vastly improved. There are huge amounts of data being collected by the Internet and mobile applications. In addition, large amounts of computation power are available on demand through cloud computing. All these three factors have led to a growth in AI applications. The World Economic Forum (WEF) as well as governments around the world have predicted that AI would bring disruption into many industries. Future professionals for smart cities must also be ready for an AI pervasive workplace.

In the Diploma in Infocomm Security Management (DISM), we had not introduced a module on AI. There are two key reasons for this. It has long been assumed that a topic such as AI would be beyond the ability of students at the diploma level. There was also some resistance from the students as they could not see the relevance of AI to cybersecurity. In the last two years, innovative AI cybersecurity companies, such as Darktrace, have removed some of the concerns about relevance. To overcome the two hindrances, we have started introducing AI into the course through project-based learning.

In this paper, we will describe our experience with using project-based learning to introduce AI into a cybersecurity course. The first is an independent study project, where AI or machine learning was used to detect malware in collection of binary executable files. The second project involved a group of final year students using Robotic Process Automation (RPA) and AI to detect the presence of web attacks. We have identified several knowledge gaps that prevented students from fully understanding the advantages of AI and also the weaknesses in AI. We are currently studying the scaffolding we need to include for such projects in the future.

Keywords: Artificial Intelligence, Machine Learning, Cybersecurity, Project-based learning

Introduction

Artificial Intelligence (AI) has gained prominence over the last few years because of novel applications of AI (Russell & Norvig, 2009) in the financial sector (algorithmic trading), in transportation (self-driving cars and trucks), in retail (predicting customer preferences and providing personalized recommendations), and even in government (optimizing use of government resources)(Harvard Business Review, 2018). The growth of AI has been fuelled by three factors: (1) better computing hardware, (2) availability of big data, and (3) on-demand cloud computing power.

Computing hardware has improved many fold since the pioneering days of AI in the 1950s. The original goal of AI was to create computer programs that could simulate intelligence behaviour that would be indistinguishable from that exhibited by an intelligent human. The researchers originally thought it could be accomplished in a few short years. However, they underestimated the difficulty of the tasks and were hampered by the computational power available in their day. Fast forwarding to 2018, the already massive computational power of today’s processors (CPU) can be further augmented by thousands of parallel computational units found within each Graphics Processing Unit (GPU)(Bengio, 2009).

The second factor that has led to an “AI Spring” is the availability of large amounts of data from devices, applications and sensors. This large volumes of data has been termed as big data. Big data is difficult, if not impossible, to use without AI (Goodfellow et al., 2016) techniques to sift out and extract useful knowledge from it. AI helps to identify patterns that would not be recognized by human eyes. AI is able to group similar data together and detect anomalous behaviour (Goel, 2011).

The third factor is the availability of warehouse-sized computers to organizations and individuals’ on-demand through cloud service providers (Patil et al., 2017). Many cloud service providers are providing computation-intensive virtual machines that have GPU accelerated processing capability. Improvements to hypervisors have enabled GPUs to be virtualized such
that its computing resources can be shared by several virtual machines running within the data centre.

Motivations

AI has found many applications in the area of cybersecurity ranging from malware detection, to user-entity behaviour analytics (UEBA), and threat intelligence. However, in the Diploma in Infocomm Security Management (DISM), we had not introduced a module on AI for the students. There are two key reasons for this. It has long been assumed that a topic such as AI would be beyond the ability of students at the diploma level. There was also some resistance from the students as they could not see the relevance of AI to cybersecurity. In the last two years, innovative AI cybersecurity companies, such as Darktrace, have removed some of the concerns about relevance.

To overcome the two hindrances, we have started introducing AI into the course through project-based learning. In so doing, we have two-fold objectives. The first is to understand some of the gaps in the student pre-knowledge that need to be addressed (Steeg, 2013) before they embark on learning AI. More specifically, we were especially concerned that students at the diploma level may not have the basic mathematical background to facilitate their understanding of AI. In addition, students may need to use software programming tools such as R or Python libraries which could be new to the students. The second objective is to understand what learning strategies (Blumenfeld et. al., 1991) would be most effective and any necessary scaffolding that should be included to facilitate student learning.

Approach

Our approach is to introduce AI into the course through project-based learning. The first project we selected was an individual project. It was a project for the independent study module (Brown, 2002). This students taking this module are those with higher ability. In this particular project, the student assigned, LKM, had expressed his own personal interest in AI before embarking on the project. Each independent study project has a project supervisor/tutor assigned to student. For assessment, the supervisor and a second examiner would conduct two assessments. One assessment is conducted mid-way through the project and the other final assessment is conducted at the conclusion of the project. The project scope was defined by the supervisor. For this project the scope was defined to be investigating the use of machine learning to detect malware in executable binaries. Students doing the independent study module have to be self-directed in their learning. The supervisor assigned would only provide some guidance or coaching if the student gets stuck during some stage of the project. Student have to find their own learning resources and conduct their own research. No scheduled tutorial or class time is provided to the student with the supervisor.

The second project selected was a group project involving a team of 5 students. This project is for the capstone project module (which we name the final year project or FYP). The project scope is defined by the project sponsor and not by the team itself. The project scope assigned to the FYP team is to investigate the use of Robotic Process Automation (RPA) and Cybersecurity for detecting website defacement. For this problem statement, the students were asked to investigate the use of AI techniques to detect defacement of websites from the visual snapshot instead using a signature-based approach on the HTML and JavaScript files. This is to avoid false positives where content has modified intentionally. In particular, in dynamic web sites where content is changed frequently it is difficult to detect defacement using a signature-based approach. For assessment of the FYP, one assessment is conducted one-third (1/3) way through the project and the other final assessment is conducted at the conclusion of the project. The students do not define their own scope for the project, but they are responsible to do their own independent research and obtain suitable learning resources to understand the scope better. For the FYP project, the approach is more structured than the independent study project. There is scheduled class time for the supervisor to meet with the project team on a weekly basis. However, supervisors do not provide additional teaching to the students. The supervisor’s role is to ensure the project follows the timeline. For the FYP project, the students are required to adhere to an Agile Methodology for project management.

Tools

AI can be implemented in a number of programming languages including Python (Numpy, 2018), C++, Java, Lisp, Prolog, Clojure (Lisp like), JavaScript, and R. We have decided to use Python (Pandas, 2018) as the programming language for the projects. This is because Python has gained adoption for many machine learning (Scikit-learn, 2018) and deep learning tools (Keras, 2018). In addition, Python is also suitable for Big Data, which an important driver for AI. There are Python libraries for Hadoop and Spark Big Data platforms.

For development and rapid prototyping, the Python Jupyter notebook allows for integration of documentation, graphs, tables and Python code seamlessly. It provides a common language for different developers to share code, data and algorithms. Notebooks can be shared with others using email, Dropbox, GitHub and the Jupyter Notebook Viewer.

The Jupyter Notebook is an open-source web application that allows students to create and share documents that contain live code, equations, visualizations and narrative text. Uses include: data cleaning and transformation, numerical simulation, statistical modelling, data visualization, and machine learning. The students’ code can produce rich, interactive output: HTML, images, videos, LaTeX, and custom MIME types (see Figure 1).

It is possible to configure the Jupyter Notebook server as a public server such that multiple users can connect to it and share notebooks from the same public server. There are public servers available such as the notebook viewer
server, NBViewer (nbviewer.jupyter.org/) which allows users to view (but not edit) the notebooks shared by other students. This also allows students to display a portfolio of their work to the public.

Figure 1. Python Jupyter Notebook

Both the project students used the Python library Tensorflow (www.tensorflow.org). TensorFlow (Tensorflow, 2018) is a mathematical library that contains routines to make it easier to implement machine learning algorithms such as neural networks and deep learning. In addition, higher-level APIs such as Keras (www.keras.io) enable deep-learning architectures such as convolutional neural networks and recurrent neural networks to be implemented conveniently. The students ran most of the TensorFlow experiments on their own laptops. However, the FYP project students also ran the TensorFlow model training process on cloud services because the training process took hours on their own personal laptops for the larger snapshot images of web pages that they were using. Data preparation of the images was done using the Python Pillow library (python-pillow.org) which is a Python based imaging library.

Another Python library that the students were able to use is the scikit-learn (scikit-learn.org) machine learning library. Data wrangling is done using the Pandas library (pandas.pydata.org) and matrix / vector operations with Numpy (www.numpy.org). In addition data visualization used the python plotting library Matplotlib (matplotlib.org) or Statistical Data Visualization library Seaborn (seaborn.pydata.org/)

Training the computationally intensive deep learning models on the students’ laptops took long periods of time if the training data were large. For example, using 1024x768 sized snapshots of the web pages as training data resulted in 2 hour long training periods on the student laptop. As students have to use their laptops for different classes at different venues, they often could not complete the training cycles in time. Aborting the training, meant restarting the training epoch from the beginning again later.

There are several cloud providers that provide cloud services suited for machine learning and for TensorFlow. Google provides the Cloud Machine Learning Engine (cloud.google.com/ml-engine). Amazon AWS provides support for TensorFlow using the Amazon SageMaker (aws.amazon.com/tensorflow/). On the Microsoft Azure Platform the Data Science and Deep Learning Virtual Machines (DSVM) supports running TensorFlow and other machine learning tools (azure.microsoft.com/en-us/services/virtual-machines/data-science-virtual-machines/). There are smaller cloud providers that offer GPU accelerated virtual machines (VM) such as Nimbix (www.nimbix.net/cloud-computing-nvidia/), Paperspace (www.paperspace.com), and FloydHub (www.floydhub.com).

Figure 2. Deep Learning Convolutional Neural Network

Results and Discussion

We decided to measure the projects based on the project deliverables and student learning outcomes. The different measure dimension are indicated on the left. For each project, we assigned a value to indicate the quality of the outcomes; where 1 is the least and 5 is the best. Table 1 indicates the project outcome based on the measures we have selected.

<table>
<thead>
<tr>
<th>Measures</th>
<th>Individual Project</th>
<th>Group FYP Project</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project report</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Project code deliverables</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Student learning of AI concepts</td>
<td>5</td>
<td>4</td>
</tr>
</tbody>
</table>

We also decided to perform some qualitative assessment of the project outcomes by surveying the students for the responses. The questions we asked and their responses are indicated in the Table 2. For the group
project, the response returned is the group response reached after the five students had some discussion among the group members. For the individual project, the response is that from one single student.

Table 2  Project Qualitative Assessment

<table>
<thead>
<tr>
<th>Questions</th>
<th>Individual Project</th>
<th>Group FYP Project</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top mistakes made?</td>
<td>the model may be build with no issue, but the accuracy is not guaranteed.</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>you can just code without understanding the math: This is one point that I found</td>
<td></td>
</tr>
<tr>
<td></td>
<td>that I am the most wrong about.</td>
<td></td>
</tr>
<tr>
<td>Data selection / Data Preparation?</td>
<td>The selection of data was done with caution, since I need to make sure that the</td>
<td>We did not adequately select the data. Needed to randomly generate data using a</td>
</tr>
<tr>
<td></td>
<td>data are unpacked and not using custom packer that cannot be decrypted.</td>
<td>script or manually collect data.</td>
</tr>
<tr>
<td>Computing resources adequate?</td>
<td>The computer that I worked on with my training did have enough resources, .I have</td>
<td>Insufficient computer resources. Windows IO is slower than Linux, so when dealing</td>
</tr>
<tr>
<td></td>
<td>spent most of my time working on a smaller dataset to get the model building code</td>
<td>with a lot of files there will be significantly more time needed. This issue is</td>
</tr>
<tr>
<td></td>
<td>correct. Maybe if I really needed accuracy, and have a large enough dataset that</td>
<td>only prevalent when dealing with large amounts of data.</td>
</tr>
<tr>
<td></td>
<td>will require the laptop to be left on from more than a day, I will be looking at</td>
<td></td>
</tr>
<tr>
<td></td>
<td>cloud solution.</td>
<td></td>
</tr>
<tr>
<td>Any helpful online resources?</td>
<td>(many youtube links and github repositories provided)</td>
<td>Sentdex youtube, he referred to online resources, such as</td>
</tr>
</tbody>
</table>

When comparing the project outcomes for both the individual project and group project, we found that the group project generated better deliverables because of the combined effort by the group. They were better able to divide the tasks and work done. However, the learning outcomes were better for the individual project because he had to learn and do everything by himself. Despite the lack of structure in the independent study project, the student also reported that he felt he learnt more from the mistakes he made.

From the qualitative assessment responses, the individual project student did more reflection on his mistakes. He also confirmed what we had suspected would be a problem. He mentioned that it was a mistake to start to code without first understanding the mathematics behind the algorithm and the effects of tweaking various parameters. The student reported that this resulted in, “I know it works, and how to make it work, but have no idea how it works situation”.

Data selection and data preparation were issues in both project, but students were able to overcome them. We found that the lack of computing resources was not a problem where the amount of data was not sufficiently large or the machine learning algorithm used is not deep learning neural networks.

Students could learn from many online resources from youtube and github. Some of online resources provided code examples as well. However, it is difficult for students to gauge the accuracy of these online resources and if they lead to future misconceptions.
One of our concerns was the need for scaffolding in the projects. For the more structured group project, the student did not mention any need for scaffolding. However, for the individual project, the student felt that he needed more coaching at the beginning of the project so that he could generate more ideas. He also mentioned that he thought the being able to make mistakes helped in his learning. However, he was frustrated by moving in the wrong direction during the project but he did not realise it. He reported, “it is essential that the lecturer make sure that the student don’t stray to a wrong concept, or get stuck for too long.”

Conclusions

AI could be introduced to diploma students through project-based learning. Students have to be self-directed in the learning in order to overcome difficulties such as gaps in their pre-knowledge. However, many resources are available online to help students self-learn concepts even in the absence of formal lessons by their supervisors. Even though there are many online resources, students do encounter difficulty making correct judgements about the effectiveness of the algorithms. Beyond simple measures such as accuracy or recall, students also need to consider if the model has inherent bias or problems of overfitting. Students have difficulty understanding the need for the model to be generalizable in order for it to be usable for future examples.

One of the gaps in the student pre-knowledge is in the understanding of linear algebra for machine learning. This topic in mathematics is not covered in the present syllabus of the mathematics module taken by the students. Moving forward, we would plan to include a tutorial or workshop on linear algebra for machine learning for the students prior to them embarking on such projects.

We concluded that we should include some scaffolding for the independent study projects because students need some additional structure in their learning in order to be more effective in grasping new concepts such as AI concepts. One scaffolding strategy is to have coaching sessions scheduled at regular intervals with the student doing the independent study module.

For the group FYP projects, where students have the benefit of learning collaboratively and also where there is a more structured approach to their project, we concluded that perhaps a curated set of reference learning materials would be helpful to the group to embark on the project together. This also helps the students to build a common vocabulary in reference to AI concepts. The common vocabulary would help them communicate and collaborate better on the project.

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References


IMPROVING CRITICAL THINKING AND MEDIA AWARENESS THROUGH CLIL

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Abstract

As educators, we should develop in our students an intellectual stance of healthy skepticism, so they become wary of simplicity and directness. This is essential to citizens who are bombarded daily with messages designed by professionals to influence their thinking as consumers and as voters. Teaching critical thinking in relation to media studies is a highly effective means to achieving this goal. Critical thinking in relation to media studies can focus on the development of students’ ability to judge the veracity of information sources. This can be accomplished by implementing CLIL classes focused on examining English-language news sources for trustworthiness. Such classes could be implemented during high school or the first years of university, in a Global Issues or similar social studies class. In this course, students would read news articles at home to discuss at school during the following lesson. The challenge is having students use English to discuss news sources, so the articles studied should be kept below the students’ actual English reading level. Students identify differences between news sources, and discuss what effect these differences had on their relative trustworthiness, all the while providing support for their choices. Teachers could employ role-playing, construct debates, have students draw pictures to illustrate ideas, or even write their own news stories. Because this is a CLIL course, new content and lexical items should be kept to a minimum. While teachers can provide guidance, suggestions, and clarification, the process of inquiry should be driven by students: the development of critical thinking skills requires a great deal of self-reflection; it cannot be taught. By exploring this topic in a second language, students gain experience with how language choices shape discourse. Students would also learn how to examine sources, and to discern emotional appeal from rational argument. There are many benefits to such a course: 1) increased awareness of news and events outside of student’s own country, 2) increased attention to connotation and nuance in English, 3) increased sensitivity to how language is used, and 4) increased opportunities to discuss and be aware of current events.

Keywords: critical thinking, media studies, CLIL, English, second language, global education

The Importance of Critical Thinking Skills

The goal of education must be more than the training of new workers; it must be the development of new citizens. And in today’s world, that means fostering students’ ability to consider themselves as not only citizens of a certain country or culture, but of a globalizing society.

In the context of fostering students who are more able to consider themselves, and their positions, in a global network of people, the ability to critical analyze one’s sources of information, and the communicate effectively with others about the relative reliability of such information sources, is an essential skill to becoming an productive member of societies. Critical analysis of information sources is one aspect of critical thinking. Classes designed to expose students to various types of news sources, to get them thinking about these news sources, and to making decisions about which are more trustworthy, can be vitally important to global education.

The importance of critical thinking to society cannot be understated. Unfortunately, there is no single definition that satisfies everyone; but a key aspect of critical thinking necessary to its definition self-reflection. This definition by “The Foundation for Critical Thinking” is a useful starting point: “critical thinking is that mode of thinking … in which the thinker improves the quality of his or her thinking by skillfully analyzing, assessing, and reconstructing it” (2015). Critical thinking is a skill, a skill based on self-reflection and self-awareness of ones own biases and presuppositions. As with any skill, it does not come naturally; it requires cultivation, guidance, and practice from a young age.

Critical thinking enables members of a society to be better able to perceive their relationships to other members of their community, and better able to fulfill their role as effective citizens. People who lack critical thinking skills have, for example, difficulty forming independent opinions and making independent decisions: actions we educators genuinely wish our students could master, especially in a time of increased reliance on social media for news and opinion confirmation, two activities which can lead to a narrowed worldview.

Critical thinking “entails effective communication and problem-solving abilities, as well as a commitment to overcome our native egocentrism and
sociocentrism” (Foundation for Critical Thinking, 2015). “Egocentrism” refers to an inability to consider the opinions of others; and “sociocentrism” refers to the assumption that one’s own social group is always correct. Neither mode of thinking is valued by societies desiring members that are conscious and respectful of other people’s cultures and beliefs. Also, [considering the rights and needs of others does not come naturally,” says Dr. Kim O’Reilly (2008). Students generally cannot develop critical thinking on their own; that is why education is so important. Additionally, humans privilege their own points of view, and tend to seek those out for confirmation via social media, which leads to increased egocentrism and sociocentrism. As educators within increasingly globalized societies, combating these mindsets is essential to enabling students to make well-informed decisions, both in their school years and in their adulthood.

Examples of egocentrism and sociocentrism could easily be seen in the 2016 U.S. Presidential campaign, and the continuing divisiveness of American politics since that time. In the U.S. and across the world, people watch with alarm Donald Trump, the most recent President of the U.S.A., insistent that he is the best, the most intelligent, and most productive President in history (egocentrism) and see his calls to “Make America Great Again” as a thinly-veiled repetition of the idea “America is the Greatest” (sociocentrism). The divisiveness between Trump supporters and Trump criticizers has only increased since his inauguration. It is not so much that Donald Trump as President is a problem (though few outside of his supporters would argue it is not); it is a significant problem in a democracy. When politicians can exploit their supporters distrust—and even complete rejection—of information from outside their own ranks, the foundations of democracy are weakened.

Lack of Development of Critical Thinking Skills

Simply put, the problem arises from a lack of educational focus on critical thinking. In America, the formal teaching of critical thinking typically begins at university. For those who do not attend university, however, the recognition of and training in critical thinking is lacking. These people tend to have a lower skill in critically examining claims made in various media. It is no coincidence that the majority of people who voted for Donald J. Trump for President hold no college degree. In fact, according to the Pew Research Center: “Trump’s margin among whites without a college degree [was] the largest among any candidate in exit polls since 1980” (Tyson and Maniam, 2016). This paucity of educational focus on critical thinking is not, of course, limited to the U.S. Japanese educators in particular lament their students apparent inability or disinterest in forming independent opinions and analyzing information sources.

A lack of critical thinking skill leads to an increased susceptibility to false or misleading news. With an increasing number of young people getting their news online, exposure to false or misleading news can only increase, as the tools for ensuring the reliability of online news do not exist in any meaningful sense. Research finds that around half of America’s young adults get their news from online platforms, and the researchers say this percentage will be even higher in the future (Mitchell, Gottfried, Barthel, and Shearer 2016). With an increase in online consumption of news and the online sharing of news sources, the need for critical evaluation of these news sources increases. Therefore, there is a great need for educators to develop students’ abilities to question sources of information, recognize problems with those sources, and formulate their own methods of overcoming these problems.

Critical Thinking and Media Studies

Teaching critical thinking in relation to media studies is a highly effective way to create better educated, more aware global citizens. To improve global education in Japan, educators must develop students’ ability to judge the veracity of information sources. This can be accomplished by implementing CLIL classes focused on examining English-language news sources for trustworthiness. By actively engaging students in this discussion, and encouraging them to discuss the issues together in English, a heightened awareness of language, of discussion, and of needs for reliability can be fostered.

Such classes could be implemented during high school or the first years of university, in a Global Issues or similar social studies class. Of course, it would be better to begin training students in critical thinking at an earlier age, and that might be possible in terms of other subjects, but to do so in the context of evaluating the reliability of news sources, high school or university students might better be able to engage with the subject and materials.

There are many benefits to such a course: 1) increased awareness of news and events outside of Japan, 2) increased attention to connotation and nuance in English, 3) increased sensitivity to how language is used, and, of course, 4) students will be aware of and discuss current affairs.

As students learn to evaluate the trustworthiness and reliability of news sources, they will also learn to communicate with each about these issues in a critical fashion. Active learning plays a key role, in that students must engage each other in discussion in order to improve their critical thinking skills.

Proposed Curriculum

These courses should be conducted in English, with a CLIL approach. CLIL stands for “Content and Language Integrated Learning,” which places, in this case, the academic focus on media studies, not on English language acquisition. Learning of English comes out of the students’ engagement with the content, and the English used in the lessons arises out of its necessity for communication between students and teacher on the subject. New vocabulary should be kept to a minimum.
whenever possible, with the focus of activities being to promote active communication between students in English. The vocabulary and grammar used must be that which is necessary for the students to effectively engage with the materials and with each other. The focus of the lesson is to explore the materials and gain a better understanding of the subject, not necessarily to improve the students’ use of English as a second language.

Essential language-acquisition activities should be a part of each lesson: speaking, listening, reading, and writing. The preponderance of class time would be devoted to reading and speaking; listening and writing would comprise a smaller percentage of time. Of course, these allotments are at the discretion of the individual teacher, dependent upon the needs of the students and the teacher’s own particular educational approaches.

Students would read news articles at home, preferably with questions to guide their reading and consideration of the articles. These articles and questions would then be discussed at school during the following lesson. Because the challenge is having students use English to discuss news sources, the articles should be introduced using a scaffolding technique that step-by-step enables the students to engage with the materials. The reading-level of the materials should be kept at or just above the students’ actual English reading level. There are sources available online for both determining the reading levels, and for providing different reading levels of articles. For example, “Breaking News English” (https://breakingnewsenglish.com/index.html) is an online site that provides news articles tailored to differing reading levels.

Each lesson should begin with a question to engage the students in the topic. The purpose of this question is the get the students thinking about the subject in English, and to establish an English-predominate environment. This also enables the teacher to identify student strengths and weaknesses in regards to the day’s material, and to tailor the subsequent lesson steps accordingly. This is a key component in a CLIL approach: lessons must be adapted to the students needs, which may require fine tuning in lesson depending on what the students have already mastered or what they are struggling with.

The teacher would then show another news source on the same event students had read about at home. Ideally, this news source would provide a different take or interpretation of events. It is essential that students are introduced to differing viewpoints of events.

One of the end-goals of the course is to get the students generating critical questions about news sources, so the teacher should be modeling such questions throughout. For example: “Who is the source of the information? Does the source have training in that area?” Students need to learn to extrapolate information from a news source, or to research that information on their own.

The goal is to identify differences between the two sources. Students would then work in groups to discuss what effect these differences had on the relative trustworthiness of each source. Finally, students would rank sources in order of veracity while providing support for their choices.

Teachers could employ role-playing, construct debates, have students draw pictures to illustrate ideas, or even write their own news stories. The main goal is to get students exploring the topic in a second language and to increase their sensitivity to how language shapes discourse; also, we could help them recognize biased language choice, examine sources, and discern emotional appeal from rational argument. This is best accomplished by ensuring class time stays focused on students, with the teacher acting less as a lecturer and more as a guide to both English and to critical thinking.

Student Evaluation

Frequent questions are raised on how to evaluate or assign students grades in such courses. Do we focus our evaluation on their English ability? their vocabulary retention? their mastery of the grammar? The answer is: none of these, necessarily. In a CLIL approach, students should be evaluated on their engagement with the content and with each other.

(Before presenting some practical suggestions, let me state that in my experience, formal evaluation of student performance does not necessarily enhance the educational quality of a lesson. For a variety of reasons—all of them well documented in the educational literature—some students react well and some react negatively to evaluation. This author is in favor of removing evaluation from lessons in order to encourage participation and reduce apprehension about the correctness of the language used during lessons. The main focus of these lessons is, again, communication through English and the development of students’ critical thinking skills.)

Consider the following recommendations, understanding others will of course exist:

1. Peer evaluations: at the end of each lesson, students assign their group members a score for the day’s participation. Teacher takes the average score for each student.
2. Final presentations: students give presentations at the end of the course, in English.
3. Written essays, either individual or group work.
4. Continual assessment based on in-class participation, regular quizzes, and peer evaluations.

Conclusion

Because we are teachers as well as concerned citizens, we should be developing in our students an intellectual stance of healthy skepticism, so they become wary of simplicity and directness. Simplicity and directness of speech are not necessarily hallmarks of honesty and good intentions; they are key ingredients in effective marketing and political propaganda. Understanding this is essential to citizens who are bombarded every day with messages designed to influence their thinking as consumers and as voters. In
this Information Age, if we wish to foster effective, thoughtful, and well-informed citizens, we need to develop their critical thinking skills. Too often, propaganda is being substituted for ideas and complex discussion, feelings for knowledge and wisdom. People who lack experience and development in media analysis and critical thinking skills find it harder and harder to discern bias in news media even though they must form opinions on matters of real importance—and it is increasingly difficult to discern what is important.

U.S. voters choosing Donald J. Trump as their President was a reminder of how difficult our task as global educators remains. A significant portion of the U.S. electorate rejected the complexity of political discourse and demanded the simplicity of a straight-talker and deal-maker, and the continued rhetoric and policies of this President confirm that this is what his supports most value. What is more, media sources are divided into “fake” and “not fake” based more on the confirmation of those sources to preexisting beliefs rather than critical analysis, and this is detrimental to the health of free societies.

It is vitally important for educators to help students become citizens who can make well-reasoned, well-informed decisions independently. As Aldous Huxley rightly pointed out, one of the greatest dangers to Democracy is a population unaware of the use of language to mold opinion. Teaching courses in how to analyze news media and determine what is a reliable source for information is an essential first step—and if we can do that while improving our students’ English, so much the better.

References


A KNOWLEDGE-CAPTURE REPORT ON LECTURER'S SPECIFICATION OF NATIONAL INSTITUTION OF TECHNOLOGY (NIT)

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Abstract

Teachers in vocational schools in Thailand have been found unqualified, which have affected teaching and learning quality. OECD Reviews of Tertiary Education shows that the National Institute of Technology (NIT), Japan, has operated best practices in its personnel management system, particularly on the lecturers’ specification. So, the aim of this study is to conduct the knowledge-capture in order to illustrate NIT’s lecturers’ specification and diagnose its achievement factors in personnel management. This work consists of two parts: firstly, the documentary study; and secondly, the in-depth interview and focus group discussion. In the first part, documentary data on NIT’s lecturers’ specification and personnel management were collected from previous research papers, articles, reviews, reports and related institution publications. Then, the interview items on achievement factors in personnel management were set and investigated by three experts. They were applied for the in-depth interview and focus group discussion in the second procedure. Fifteen key informants in Japan, from two NIT colleges: Kumamoto and Ube; and its head quarter: Tokyo, were selected to be involved. All collected data were synthesized using data analysis method. The finding on NIT’s best practices regarding lecturers’ specification revealed five important qualifications, namely, skills and experiences; educational level (Ph.D.); educational background; academic and research publication; and self-reputation (attitude, vision, belief). In addition, the finding on the diagnosis of its achievement factors in personnel management revealed in two portions: external and internal. External factors found in this study were 1) NIT’s educational system 2) NIT’s networks among all related campuses, companies, and manufacturing 3) organization rules and regulations and 4) organization explicit roles and structures. Internal factors were 1) self-belief in their organization, system, themselves, and learners 2) value 3) discipline 4) devotion 5) willingness 6) loyalty 7) good relationship. Therefore, Thai teachers’ personnel management regarding lecturers’ specification should be developed by considering the application of NIT’s best practices. After that, the experimental pilot project should be held in order to examine its outcomes on the teaching and learning quality in the institutions which conduct new teaching and learning system.

Keywords: NIT, personnel management, teacher, specification, Japan, Thailand, system, factor, best practice, lecturer

Introduction and pedagogy

The process of knowledge management (KM) by means of knowledge capturing was a method an organization used to explore the best practices from external sources. Explored knowledge gained from the collaboration with other organizations, outstanding partnerships, would benefit to its efficient and effective human resources development. (Panich, V., 2003; Nonaka, I & Takeuchi, H., 1995; Turban, E & Aronson, J., 2001) Thailand has been facing the issue on teachers’ personnel management in specific vocational institutes, especially in teachers’ specifications criteria. Report of the meeting between Thailand’s Office of the Teacher Civil Service and Educational Personnel Commission (OTEPC) and National Institute of Technology (NIT) or KOSEN, (OTEPC, 2018) revealed an incompatibility of teachers’ specification which could not serve KOSEN to recruit qualified teachers for KOSEN lecturers’ specific tasks to work in Thai-Japanese Institute of Engineering and Technology. This affects the quality of teaching and learning in schools that provide new teaching system in Thailand like KOSEN. The interview of Thailand’s Office of the Vocational Education Commission (OVEC) staff (Interview, April 20, 2018) also showed that Thai teachers who had been selected into the system encountered 2 crucial problems. Firstly, they lack of appropriate quality for teaching and learning. High expectation of schools executives and parents forced them to create high quality teaching and learning. Secondly, they lack of motivation which affected on their ability to improve their morale and performance. To deal with these problems, OVEC staff suggested that the relevant educational agencies should develop
appropriate teachers’ specifications criteria for the schools that provide new teaching and learning or bilateral education. Thus, OTEPC as a sector responsible for Thai teachers’ recruitment system development should consider and review its current policy, rules, laws, regulations, and criteria with the support of outstanding external sources like NIT best practices.

Importance of recruitment system
Barber, M., & Moursheed, M. (2007) indicated that an education system cannot exceed the quality of its teachers. Teachers’ quality is one of the main factors that affect learners’ quality. Therefore, recruiting the right people to become teachers and developing those people to be effective teachers is the most important aspect of the world’s best performing school systems. Mathis & Jackson (2010) indicated that the most important mission for any organization’s success is the human resources management of the organization through the recruitment, selection, and placement process. The report of TDRi research (2016) and Thai Publica (2014) also confirmed that standard of teacher recruitment system is important to effective teaching and learning. Orawongsuphatat, C. (2013) supported that the key to successful organization is the person who meets the needs of the organization. This will be a valuable and important asset to drive the organization to achieve its goals and objectives. Smithikrai, C. (2013) stated that each job is different. Each person has different attributes, knowledge, ability, skills, and personality. To deploy qualified person with the appropriate tasks will produce the best results for an organization. This can enable them to work effectively and satisfy to engage organizational commitment. Unqualified personnel recruitment, selection, and placement resulted in unqualified staff and organization failure eventually. (Heneman & Heneman, 1994)

Japanese Identity
Japanese identity is very important when addressing Japan organization or institution achievement. Tsutsui (1997) stated that Japanese management developed from the cultural heritage and reflected traditional values of “groupism” - feeling of dependency and high regard for harmony. Besides, a strong sense of “we” versus “they” and emphasis of our group was strong in Japanese society. (Caudill, W., 1970) Japan society is a masculinity society which the preferences for the achievement, heroism, assertiveness, and material rewards for success are value. Japanese value more success and challenge. Khlangsawan, Y. (2003) indicated that Japanese society is unique in terms of being a society of unity and social order which is influenced by culture and tradition inherited from the past. In addition, Japanese society is a strong society and most people value for success, courage, expression, challenge, and material rewards for concrete success. So, Japanese focus on the competition and long-term success in the future (Hofstede, 1981; Hofstede, 1991) Japanese organization culture was also influenced by national culture as could be seen from the organization management. It is a kind of father and son management – paternalism. It is a unique feature of the management of Japanese organizations that grow from cultural heritage and reflects traditional values. "Group reliance and one united." (Tsutsui, 1997) The education system in Japan themselves was influenced by traditional culture, and is recognized as a system of education that emphasizes collaborative unity and social order. Khlangsawan, Y. (2003) summarized that after World War II, when Japan needs to recondition their economy, they aimed at recruiting and satisfying talented people to work in the organization or study and work in educational institutions. The study focuses on education for the benefit of the public and the nation not education for the benefit of an individual. Japanese people always remember that national needs come before personal needs. (Wray, H. 1999) It is concluded that Japanese society and culture have a great influence on the lives and beliefs of the people in its society as well as in its educational system.

Best practice in NIT personnel management
The 1st KOSEN was established in 1962. Now, there are 51 KOSENs 55 campuses nationwide in Japan. After World War II, there was a huge higher educational shift in Japan. It shifted from elite to mass and a trend towards more “vocational” degree program has been introduced. (Newby, H. et al., 2009) National Institute of Technology (NIT) Japan or KOSEN which offer more of a fit-for-purpose license to engage in professional practice served to this policy aim. OECD Reviews of Tertiary Education (Newby, H.et al., 2009) also showed best practices in its own individuality and distinctiveness in NIT’s educational system: the co-curriculum between practice in companies and theories in class. Besides, the focus on regular production of research studies can improve the quality of both teachers and students. Accordingly, this opens the opportunities for students’ success in jobs finding. 40% of graduates could take further education or advance course in famous universities and 57% could obtain job offers from well-known industries, manufacturing, maintenance service, IT, and etc. worldwide, and the rest 3% aimed for other purposes.

Figure 1 NIT students’ success in jobs finding

Careers for KOSEN Graduates

From Introduction of KOSEN, Presentation of NIT’s president: 9th October, 2017 Bangkok, Thailand
To successfully run this newly trend of education system, NIT has to meet the challenge of international competition in research. Therefore, NIT must be
internationally competitive with respect to the recruitment and retention of high-impact researchers. Focusing on NIT’s policy of lecturer recruitment, most of NIT’s lecturers or academic staff must hold Ph.D. degree due to NIT mission and the value of the country. Its mission is to produce research paper and create innovation while the value of the country is to maintain the quality and standards of education in order to develop industrial workforce. Thus, it is a common belief that one of the best practices leading to NIT success is its lecturer’s quality and specification.

Based on the above reviews, the study on NIT lecturers’ specification had been conducted. OTEPC, an office responsible for the establishing of teachers’ specification, raised a collaborative project with the National Institute of Technology (NIT) to study NIT lecturers’ specification. It aimed to illustrate the results of knowledge-capture on lecturers’ specification of National Institution of Technology and diagnose its achievement factors in personnel management.

Materials and Methods

This qualitative research divided into 2 sessions: the documentary study session and the in-depth interview and focus group session. Materials and methods of each session were as follows.

Material Firstly, documentary study and meeting report forms, investigating by three OTEPC and NIT experts, were used to explore the issues on teachers’ personnel management, the importance of recruitment system, best practice in NIT personnel management and Japanese identity. Secondly, a semi-structured interview items, investigating by three OTEPC and NIT experts, was designed regarding NIT’s structure and context and the best practices of its recruitment system and lecturers’ specification.

Methods Firstly, data were collected from previous studies, articles, report, reviews and related institution publications both in paper and online. In addition, three meetings between OTEPC and NIT were set for the discussion regarding the overview of personnel management. The reports of the three meetings were reviewed, then, all data were analyzed. Secondly, data were collected via in-depth interview and focus group discussion. Purposive sampling with snowball method was used to select the key informants. Fifteen key informants: executives; academic staff; and administration staff from Kumamoto and Ube colleges (25th Feb.-2nd Mar, 2018) including one executive at NIT head quarter in Tokyo were involved. Focus group discussion, interview, and campus context were observed and noted. All data collected were analyzed using content analysis method. (See Figure 2)

Results and Discussion

The findings of this knowledge-capture report revealed 2 parts: lecturers’ specification and NIT achievement factors in personnel management.

NIT’s lecturers’ specification

NIT lecturers’ selection has been done by the committee, namely, “Personal committee” which is the main committee appointing to select new academic staff in a transparent and independent manner. The lecturer applicants need to hand in their outstanding documents such as resume, list of articles, books, patents, conference presentation, the summary of 3 major articles, list for the past 10 years research grants, their achievements record, and 3 essay about the aspiration on KOSEN’s education, researches, and students guiding. Their resume and documentations will be screened, examined, and reviewed by the judges. The selected applicants will be interviewed and they have to make a presentation and the trial class in front of the judges. Three criteria were set with equal weight: attitude was 15; content was 15; and overall rating was 15, so total were 45. Applicants’ way of talking, voice projection, eye contact, way to answer the question, and way of convincing people will be evaluated for their attitude. The appropriateness, clearness, balance of the applicants’ essay, presentation, trial class, and interview will be evaluated for the content. Applicants’ appropriate qualifications for being KOSEN teacher will be evaluated for their overall image. After all, the final selection will be made. The transparency of NIT lecturers’ selection is known as one of NIT outstanding reputation.

NIT lecturers’ specification consisted of 5 core criteria. The first core criterion was lecturers’ educational background. They must hold Ph.D. due to NIT mission to produce research paper and create innovation and the values of the country to maintain the quality and standards of education in order to develop industrial workforce. Therefore, Ph. D. is required. The second core criterion was applicants’ interests. The applicants must hold an interest in NIT education system, eager to teach and research, have good aspiration toward teaching NIT students, interest in a collaboration and cooperation with local companies to make the contribution due to the college duty, and be ready, willing, and able to support the community which is a key mission of NIT College. The third core
criterion was applicants’ skills. The application must hold all required essential skills and other specialized skills are preferable. The fourth core criterion was applicants’ publication. The applicants must have articles published in domestic and international peer-review journals, books, patents of products’ innovation and design, conference presentation, other reputation. In addition, the applicants must be in good shape mentally and physically and be ready to perform all NIT teacher duties. Beside, maximum age may be set but not fixed or subject to special conditions. (See Figure 3)

Figure 3 NIT’s recruitment process

The excerpts from in-depth interview and focus group discussion of NIT members in Kumamoto and Ube colleges regarding NIT’s lecturers’ specification were as follows.

Excerpt 1 Lecturers’ educational background

“One of the most important requirements is having PhD degree. This is a very important requirement.”
“Teacher must have the PhD. because they must do the research.”
“We expected for PhD holder because the Japan society is expect and want the quality of education”
“Tink why KOSEN teacher is Ph.D. because teachers must instruct students in graduation research so teacher must have Ph.D.”

In-depth interview and discussion, 25th Feb.-2nd Mar, 2018

Excerpt 2 Applicants’ interests

“Teacher could interest in collaboration with local companies because one task of the college is to serve the local development”
“Main task of the KOSEN is to support the communities, therefore, our teacher or our staff must have the qualification in willing to support the communities”

In-depth interview and discussion, 25th Feb.-2nd Mar, 2018

Excerpt 3 Applicants’ skills

“Skill of the teachers important to us and we prefer testimonial from applicant’s supervisor or professor to prove it”

In-depth interview and discussion, 25th Feb.-2nd Mar, 2018

Excerpt 4 Applicants’ publication

“Publication is require for the teacher who want to be a teacher at the college”
“Applicant should have the publication in journal both domestic or international, book or others”

In-depth interview and discussion, 25th Feb.-2nd Mar, 2018

Excerpt 5 Others

“The issue of age, it depends on the position. We are not fixed”

In-depth interview and discussion, 25th Feb.-2nd Mar, 2018

NIT achievement factors in personnel management

Important factors behind NIT personnel management achievement have been revealed in terms of external and internal factors. External factors that influence the achievement of NIT’s personnel management were NIT’s education system, the invaluable networks, the explicit and transparent organization structure and rules, and the clear staff roles and responsibilities. Firstly, NIT’s education system was geared to teaching both theoretical and practical in the same weight. Besides, the focus on its research process is a main key in NIT teaching and learning which contributes to learners’ potential to create innovation. Secondly, the invaluable networks both inside and outside the country such as network of NIT colleges’, network of NIT alumni, and network of companies’ or enterprises’ have strongly been woven and tied. Thirdly, the explicit and transparent organization structure and rules and, lastly, the clear staff roles and responsibilities also influence the achievement of NIT’s personnel management. NIT structure and rules as well as staff roles and responsibilities were well-constructed. In addition, all the details of these crucial information have been shared and conveyed to all staff by NIT prior to and throughout the period they has been working in NIT. All staff received, understood, and accepted the same value since they applied and entered into NIT. Their authorization has been operated in terms of committee. NIT stakeholders, former staff, or companies could not intervene the committee operation.

The excerpts from in-depth interview and focus group discussion of NIT members in Kumamoto and Ube colleges regarding external factors were as follows.

Excerpt 6 NIT’s education system

“Engineers need both knowledge and practice skill. So KOSEN produce such students”
“We share for practice and theory as half and half because after the WWII Japan need high school on technology and engineering”

In-depth interview and discussion, 25th Feb.-2nd Mar, 2018

Excerpt 7 Invaluable networks

“The KOSEN has various partners including universities, national research institute, private enterprises and so on”.
“Our style and teaching ideology is lead by the problem base learning so that style make us can make the network with many local community, companies, enterprise and alumni is also”

In-depth interview and discussion, 25th Feb.-2nd Mar, 2018

Excerpt 8 Explicit and transparent organization structure and rules
The executive committee is one of which discussed various issue in the school management and decide the school policy. And this committee work like a control tower of the KOSEN.”

“We have clear role and rule, for instance, in the recruitment and selection. No one can involve or dominate the Personal Committee to select someone that they know.”

In-depth interview and discussion, 25th Feb.-2nd Mar, 2018

Excerpt 9 Clear staff roles and responsibilities.

“The teacher’s tasks at KOSEN are classified into three large groups. They are lecture, research and management.”

“Maintain to do the research, teaching, engine the community and consult for the student”

In-depth interview and discussion, 25th Feb.-2nd Mar, 2018

Internal factors that enhanced the achievement of NIT’s personnel management were NIT staff’s belief (1) in organization (2) in system (3) in oneself (4) in students; value; loyalty; devotion; willingness; discipline; relationship; and attitude toward problems solving. These internal factors have been observed by the researchers during the conversation of the interview, discussion, and campus tour. To the question “With the decreasing budgets and work overload you still have good attitude toward your work. They can motivate themselves under this circumstance well. What do you think? Can they accept that? Or may be how do you deal with that problem?”, one of the key informant replied that “I think this is a Japanese character, may be culture.” And, “I work for Tokyo KOSEN for 31 years; I have met the very nice and very good students. It’s my pleasure in my life. KOSEN has a big special structure between students and teachers. They have much closer relationship. It’s not only a class and teachers teach. They are more involved in each other.”

Excerpt 10 Staff’s belief, value, loyalty, devotion, willingness, discipline, relationship, and attitude toward problems solving.

Belief
“The students are very serious and have a good attitude to study.”

“Number of teachers, all branches 79 including 66 Ph.D. holders graduated by two institutions, both names are too long so that are called NIAD and JABEE for short.”

Value
“Our teachers are willing to serve the community and teach and also all of them are highly in performance”

Loyalty
“Many student apply to master degree and higher level and after they finished doctoral they come back to college”

“In Japanese society, remain the way of thinking, life and employment. If you get employ company, you keep work in the company for retirement.”

Devotion
“If you don’t gave me more salary I’ll be stay here because I think here is suit for me and enough”

Willingness
“I love to be a teacher and when I finish I come back to teach at KOSEN, I willing to teach”

Discipline
“The professor’s policy was ‘Do it yourself’. So we decided all things ourselves and we made the machine ourselves, repeating the failure. And finally we complete the machine and did the fatigue test and analyzed the data.”

Relationship
“Also we have a homeroom teacher. So teachers have sort of feelings seeing students growing up. It’s more emotion.”

Attitude toward problems solving
“I can say the diversity some problem have some opinion. Some person tries to communicate to young person, young boy and young girl.”

In-depth interview and discussion, 25th Feb.-2nd Mar, 2018

Discussion on NIT’s lecturers’ specification

Why do educational background and interests of NIT applicants that was set up as main specification of NIT’s lecturers’ influence NIT personnel management achievement? The answer related to many previous studies on Japan identity and importance of recruitment system. Japanese society values achievement and success and expect the quality of education (Hofstede, 1981; Hofstede, 1991; Bond M. H., 1991) while NIT has to meet the challenge of domestic and international competition in research. Thus, to successfully run NIT’s new trend of education system which emphasize on quality research works, NIT needs to recruit qualified people into its system. Ph.D. is the right answer for setting up lecturers’ specification on NIT lecturers’ educational background. Qualified lecturers with Ph.D. could serve those values and challenge as well as serve the students success both in furthering their education and job finding. This phenomenon confirmed by the statement of Barber, M., & Mourshed, M. (2007) that teachers’ quality is one of the main factors that affect learners’ quality. Japanese society at large is more competitive. (Hofstede, 1981; Hofstede, 1991; Bond M. H., 1991) Thus, unity of organization is dramatically important. Setting up lecturers’ interest as one of the main specification is a must. NIT right person must first hold the same interest in NIT education system, eager to teach and research, in good aspiration toward teaching NIT students, in a collaboration and cooperation with local companies to make the contribution due to the college duty, as well as be ready, willing, and able to support the community which is a key mission of NIT College. In addition, with the support of a strong society in Japanese characteristic and Japanese shared value in unity and future-oriented (Khlangsuwan, Y., 2003), a strong NIT community will eventually be created by these qualified lecturers. Accordingly, this phenomenon will enhance organization long-term success. This was confirmed by Orawongsuphathat, C. (2013) who indicated that the key to successful organization is the person who meets the needs of the organization. This will be a valuable and important asset to drive the organization to achieve its goals and objectives. Unqualified personnel recruitment, selection, and placement resulted in unqualified staff and organization failure eventually. (Heneman & Heneman, 1994)

Discussion on NIT achievement factors in personnel management

Internal factors that influenced NIT achievement in personnel management had been revealed during the staff discussion and interview. They were staff’s belief, value, loyalty, devotion, willingness, discipline, relationship, and attitude toward problems solving. Reviews on Japanese identity could explain this phenomenon. All these factors found to serve better NIT organization culture influenced by national culture inheriting from Japanese culture and tradition in the past. They were formed inside their mind during the upbringing period. This was confirmed by the studies on Japanese cultures, social order, tradition, and society
toward everything they do is the pride of the family. (Wray, H., 1999) Japanese people praise cleverness or deceit. In Japanese society, full action focuses on the benefit of the public not the benefit of an individual. (Wray, H. 1999) Japanese people praise the strength of patience and perseverance, not from cleverness or deceit. In Japanese society, full action toward everything they do is the pride of the family. (Tuntruttanasoontorn, B., 2015) In addition, most Japanese have a willingness to work hard and to persevere toward long-range goals. If a person is treated well, he works willingly and hard. (Caudill, W., 1970) The culture of Japanese organization is a kind of father and son management – paternalism. (Tsutsui, 1997) Close relationship between NIT staff was seen as a very distinctive and unique feature of Japanese organization management. It reflected traditional values of “groupism”. So, their attitude toward problems solving influenced by Japanese social order, the feeling of dependency, and high regard for harmony emphasizing collaborative unity and social order. (Tsutsui, 1997)

Conclusions

This report revealed very useful NIT best practices for OTEPC to deal with the issues of inappropriateness of Thai teachers’ specification in the schools that provide new teaching system in Thailand. Collaborations between OTEPC, OVEC, and NIT is in need for appropriate teachers’ specification and selection criteria renewing. The teachers’ specification and selection criteria must be reviewed and developed. In order to sustainably create high teaching and learning quality as well as high quality of Thai students, achievement factors both external and internal are applicable to Thai teachers’ personnel management. All external factors should be reviewed by Thai institutions prior to apply to their institutions development. However, national identity has to be educated since young. Therefore, internal factors application toward Thai staff may take times and need the involvement of the Office of the Basic Education Commission (OBEC). Due to the differences between Japanese and Thai cultures and educational system, the comparative study should be made.

Acknowledgements

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FOSTERING PRACTICAL AND GLOBAL ENGINEERS BY PARTNERSHIPS WITH THE REGIONAL COMMUNITY

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Abstract

National Institute of Technology, Ishikawa College (NIT-IC) has started an educational program since 2017, “Fostering Practical and Global Engineers by Partnerships with the Regional Community - Career Design Education through Collaboration with Local Companies”, which was adopted in FY2017 by the Ministry of Education, Culture, Sports, Science and Technology as a “KOSEN 4.0” Initiative. The aim of this program is to encourage young KOSEN students to acquire and develop knowledge, skills and mind-set of the next-generation technology. The project is systematically organized as a career design program through collaboration with local communities and companies.

This education program motivates and encourages the lower grade students to be leading engineers with lectures of experienced engineers and visits to actual production sites and working places. For the upper grade students, it provides seminars for the students to study what local companies and municipalities are working on. After the students learn the activities of the companies and municipalities, they take two weeks internship to experience actual jobs in development and production sites of the companies. Also, all fourth-grade students visit overseas factories in Southeast Asian countries, where the local companies have their production branches and interact with the students of these countries.

In the advanced course, the students take three months internship, where they try to find various problems that local companies or communities face and tackle the problems for themselves. Furthermore, some of them participate in an overseas internship for a couple of months to become a global engineer with a financial support by the Japanese government (e.g., Tobitate! (Leap for Tomorrow) Study Abroad Initiative).

The students document every event provided in the program on a portfolio with self-evaluation. The portfolio records not only engineering knowledge and skill development but also professional sense development.

This paper reports the specific contents and outcomes of the educational program.

Keywords: career design, international internship, engineering education, regional community, portfolio

Introduction

Japanese local societies like Ishikawa Prefecture are facing several serious issues, e.g. depopulation, globalization and climate change. The depopulation of the region leads to shortage of local engineers as well as shrinking of local markets. This would hinder development of advanced productions and make it difficult to maintain old infrastructures in this area.

The globalization forces the local industries to transfer their production departments overseas like Southeast Asian countries to complete with global companies and expand new markets. The climate change urges the industries to produce environmentally friendly products with a reasonable cost. KOSEN needs to not only teach technical skill and knowledge but also educate young engineers to contribute to the sustainable development of regional communities.

Under such circumstances, National Institute of Technology, Ishikawa College (NIT-IC) has started an educational program since 2017, “Fostering Practical and Global Engineers by Partnerships with the Regional Community - Career Design Education through Collaboration with Local Communities”, adopted in FY2017 by the Ministry of Education, Culture, Sports, Science and Technology as the “KOSEN 4.0” Initiative.

The project is systematically organized as a career design program through collaboration with local companies. This paper reports the specific aims, contents and outcomes of the educational program.

Aim and System of the Educational Program

The aim of this program is to encourage young KOSEN students to acquire and develop technical skills, knowledge and mindset of a global engineer. The project is systematically designed as “Career Design Program” through collaboration with the regional communities.

The program is consisted of following four subprograms:
1. “Career literacy” for lower grade students
The subprogram motivates and encourages the lower grade students to be leading engineers through lectures by professional engineers and visits to actual production sectors and working places.

2. “Career Workshop” for upper grade students

It provides seminars for the students to study what local companies and municipalities are working on. After learning the activities of the companies and municipalities, the students participate in a two-week internship to experience actual jobs in development and production sites of the companies. Also, all fourth grade students visit overseas factories of Japanese companies in Southeast Asian countries and interact with local students of these countries.

3. “Career Challenge” for advanced course students

The students take three month internship working at local companies as the normal employees to find what they can do and what they lack in an actual working environment.

4. “Global Career Challenge” for all students

Some of the students go on an overseas internship for a couple of months to prepare to become a global engineer with a financial support from the college and Japanese government, e.g., Tobitate! (Leap for Tomorrow) Study Abroad Initiative (Ministry of Education, Culture, Sports, Science and Technology, 2018).

The program overview is shown in Figure 1. Expected specific outcomes from this program are an increase in the number of students who participate in an international internship and get a job at the local companies.

ICTPS is an organization with 220 members from local companies, municipal governments and industrial societies. Its activities are to support educational and research activities of the college and connects the members with students and faculty members of the college. In this project, the members accept the students for an internship, provide information of the companies and arrange production sites and working places for the students to visit.

ICHEI is an organization comprising of 21 higher educational institutions of Ishikawa prefecture. The mission is to enhance and develop the regional higher education, culture, research and industry with collaborations among the member institutions and regional communities. The activities include sharing education programs between the member institutions and promoting collaborative educations with regional communities. In this project, ICHEI provides coordination and financial support for students who participate in an overseas internship.

The college employs two coordinators who used to be professional engineers and have experiences in industrial worlds. Their roles are to connect the students with local companies and teach business manner, culture and safety management to the students.

Career literacy

There are three fundamental components in the career design (Tazawa, 2018): Will (hope, dream and determination), Can (ability) and Must (requirement from societies) as shown in Figure 2. In the career design, students have to find what they really want to do, which motivates them to move forward (Super, 1957).

However, the students sometimes feel anxious or dissatisfied due to lack of skills and abilities, and mismatching between current study and future career. Analyzing their current situations in terms of the three components and recognizing overlapping area of the components change these negative feelings to “Hope” and “Fulfillment”. This process prompts the students to analyze their dreams and abilities as a self analysis, and study business outlines of companies as an exterior analysis. Those actions encourage them to make positive actions for realizing their dreams.

Implementation and Support of the Project

The program is implemented by whole college staff under the leadership of the president. In this program, collaborations with regional communities are indispensable. For that, we have supports from two local organizations: Ishikawa College Technology Promotion Society (ICTPS) and Ishikawa Consortium of Higher Educational Institutions (ICHEI).
what they have and do not have for achieving their career goals. In the workshop, the students think about and list up what they want to do in a future career. They put the listed items on a matrix form with a vertical axis of present to future and a horizontal axis of interests to job as shown in Photograph 1. This process gives them an opportunity to connect their present with their future and recognize the relationship between their interests (Will) and jobs (Must).

Photograph 1. Presentation in Career Design Workshop

The students train and repeat this process continuously and record the results of the process on a portfolio, which will be explained later in this report.

In a class of orientation for each engineering department, students learn about what their career and jobs as an engineer will be in each engineering field. Also, they have lectures from graduates how they build their own career as an engineer, and they visit factories and construction site to learn what are actual works and what engineers really have to do.

The third grade students visit a production sites and working places for two days outside of Ishikawa prefecture to see jobs of big global companies. Also, they have lectures from the leading engineers of the companies to learn the state of art of their engineering field and build their own career images.

For the third and fourth students, ICTPS holds a job fair in the college gymnasiums, where member companies are able to explain their own technologies and business outlines directly to the students. The college gives the students a booklet, which introduces these companies to the students for studying the companies before the fair. All the students visit at least four company booths and contact company engineers. This is the first opportunity for the third grade students to know what kind of companies are located in Ishikawa prefecture. This fair motivates the students, who were very little concerned their career, to explore their future and prepare a short period internship provided in their fourth grade curriculum.

According to the result of the survey, more than 70% of the students who attended the job fair expressed that the fair was very helpful to think about their future. We also asked the companies participating in the fair about impression of the students. They answered that the students very seriously listened to the company presentations and they had very positive impressions on the student’s attitude. 95.6% of the companies very eager to participate in the fair again.

Career Workshop

The fourth grade students have to start to think about what kind of job they are going to obtain after they graduate the college. The college provides them information on their career paths and local companies as much as possible.

Photograph 2. Job Fair Held by ICTPS in College Gymnasiums

The students take a two-week internship in a company selected based on the knowledge obtained from the job fair and graduate lectures. In the internship, they experience actual activities in the factories or government offices. Since they realize that their engineering knowledge and skills are still insufficient, they find out what they need to take up the profession, and what they would actually do at work.

After experiencing the short internship, they have ICTPS job fair again. Since this is the second time for them to participate in the fair and they have to determine and find employment in several months, they take this opportunity much more serious than in the previous one. They visit company booths that would be related to their future career. In this fair, many local companies, which are unfamiliar to the students but have great technologies, are able to present and appeal their business to the students. Therefore, this is a good opportunity for the students to broaden their perspectives of own future careers in the local companies.

In the meetings of ICTPS, we found that even local companies have a strong incentive to transfer production bases and expand new markets abroad such as Southeast Asian countries because these countries are developing their economic powers and becoming great markets for Japanese industrial productions.

Sometimes, our college graduates are in charge of the oversea operations. Since young people these days do not want to go working out of home country, the companies have difficulties to find a staff member who are able to work abroad. ICTPS requests the college to let the students have more international experiences and broaden their job perspectives to worldwide.
Considering the situations, the college takes all fourth grade students to Southeast Asian countries and let them have international experiences exposed to other cultures and customs.

Each engineering department chooses a country to visit and gives the students opportunities to meet the same age local college students and look at working environment of Japanese companies operating in the countries. Although the trip is very short, it is a first trip abroad for most students and gives a strong impression to them. Through the trip, the students open their eyes to outside of home country and understand the meaning of working abroad. Table 1 shows an example of schedule of the short trip abroad.

Table 1, An Example Schedule of Oversea Excursion for Civil & Environmental Department

| The first day | Move to the country to visit |
| The second day | AM: Meet with local students  
PM: Sightseeing |
| The third day | AM: Visit a construction site of subway station  
PM: Shopping on their own |
| The fourth day | Back to home |

The result of a survey to the students after the trip revealed that more than 90% students realize the lack of English communication skills. But, at the same time, they do not hesitate to work abroad any more.

Career Challenge

The curriculum of the advanced course includes three month internship to a local company, which is worth ten credits. The students have to take orientations and lectures about basics of internship before the internship.

In the orientation, the students learn business manners, cultures and safety management. The host companies are responsible to determine what the students are going to do during the internship, and set a goal of the student.

The students are trained by the host company as a normal employee. Some of them are involved in a research and development activities. They submit a daily report to supervisors who are in charge of looking after the interns and checking their daily activities. They also report their monthly activities to teachers in the college. The teachers and coordinators in the college visit the host companies to see how the students work. Moreover, they talk with the supervisors in the company about student’s activities as well as issues or problems if they have.

After the internship, the students make a report about their activities and self evaluation including whether they attained their goals that they set beforehand, what they accomplished and what they lack. The students hold a presentation of the report to the coordinators, teachers and host companies. The students are graded according to the evaluations of teachers and host companies based on a daily report, working attitude, the final report and presentation.

The three month internship is a big challenge for the students and help them to establish their realistic and specific future plan as an engineer. Even students who had not confidence in themselves before the internship have changed to young engineers with confidence after the internship.

The host companies deal with the student as a normal employee and strictly point them out what they lack for the job assigned. This experience motivates them to study harder after coming back to the college. Some of them determine and choose the host companies as a place of employment. Although the three month internship generally is the burden of responsibility for the host companies, they understand the importance to educate young engineering students in collaboration with colleges. It is because the internship would be long term benefits for the companies who are struggling to find young employees. We also have continuously been improving the three month internship program based on the feedbacks and constructive opinions from the host companies.

Global Career Challenge

The local companies in the HOKURIKU region comprised of three prefectures: Toyama, Ishikawa and Fukui have a strong incentive to transfer production bases abroad such as Southeast Asian countries. Many graduates are employed by those companies and some of them work an overseas branch. Therefore, those companies are looking for young engineers who are able to work in oversea environments.

Several international programs are available for our students. As we have explained in the previous part, the advanced course students are required to participate in three month internship either in Japan or abroad. ICHEI provides a competitive fund to support college students. Students propose a plan of various international activities including internship abroad for more than one month. Few of the plans are accepted and have the financial support after a rigorous screening. This support program is called “Tobitate! (Leap for Tomorrow) Study Abroad Initiative “, which is sponsored by Ministry of Education, Culture, Sports, Science and Technology. We also recommend our students to apply other programs sponsored by Ishikawa prefecture and National Institute of Technology. The students who have studied abroad and attended oversea internship share their experiences with other students through the reports and presentations. Table 2 indicates the numbers of students who participated in these kinds of international programs.

Table 2, Numbers of Students Who Attended International Internship. Short: Less than one month, Long: More than one month

<table>
<thead>
<tr>
<th>Year</th>
<th>Long</th>
<th>Short</th>
<th>Subtotal</th>
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</thead>
<tbody>
<tr>
<td>2015</td>
<td>0</td>
<td>6</td>
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</tr>
<tr>
<td>2016</td>
<td>2</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>2017</td>
<td>2</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>Total</td>
<td>4</td>
<td>19</td>
<td>23</td>
</tr>
</tbody>
</table>
The numbers of students who had international experiences as presented in Table 2 do not seem enough considering the total number of students in the college of 1100. The reasons of these small numbers are:

1. The financial burden of international programs is a serious problem for the students and their family.
2. Very few local companies that have oversea branches are able to accept the interns, because the most of local companies are small or middle-seized and do not have staff taking care of the interns.

The college set up a fund to support the students, who want to have international experiences, by collecting donations from local companies, college graduates and parents. Also, we strongly recommend the students to apply international programs sponsored by Japanese government, municipalities, industries and other various agencies.

The college has been trying to expand the international networks by attending relevant international conferences and visiting oversea branches of Japanese companies and international colleges with supports from ICTPS and ICHEI.

Career Portfolio

As mentioned earlier, it is required for a student to analyze three components and overlap them for building up his/her career. The portfolio is designed to help the student to practice this analyzing process. The structure of portfolio consists of the following steps:

1. **Will**: A student imagines his/her future as a professional engineer of around 30 years old (long-term goal).
2. **Will** and **Must**: The student looks at overlapping area of **Will** and **Must** to set a short-term goal based on the long-term goal as described in Step 1.
3. **Can** at present: The student analyses what he/she can do at this present to attain the goal of Step 2.
4. **Extend present Can**: The student makes a specific action plan of what to do, when to do and how to do.
5. **Change of Can**: The student evaluates the difference in **Can** between past and present.

The students repeat this process and record them on the portfolio every half school year. They are able to examine and recognize the change in the future image and growth in the engineering abilities from the portfolios. This enhances the self-efficacy (Deci, et al., 1985; Bandura, 1977), which will be the strong motivation for the students to challenge the next stages.

This type of portfolio is designed for the first, second and third grade students. The fourth grade students add sheets including company research results and self-introduction to previously accumulated portfolios to raise their social consciousness. Such self-analysis on **Will** and **Can** and external analysis of **Must** are continued for all years to give the students new goals and stimulate them to prepare new challenges. These analyses make students set specific goals up before an internship and evaluate themselves based on what they accomplish in the internship.

**Conclusions**

NIT-IC has started a specially designed program since 2017, “Fostering Practical and Global Engineers by Partnerships with the Regional Community - Career Design Education through Collaboration with Local Communities". The aim of this program is to encourage the young KOSEN students to acquire and develop knowledge, skills and mind-set of global engineer to the next-generation. The project developed a career design program through collaboration with local companies. The program consists of five processes: career literacy (lower grade students), career workshop (upper grade students), career challenge (advance course students) and global career challenge (all students) and portfolios that visualizes the change future career image and development in engineering abilities and global mind. Through all activities provided in this program and recorded in the portfolios, students realize the growth of themselves, of which process itself is the career design for the students to become a global engineer.

One of issues raised up in this project is lack of fund to support students to attend international conferences. Another one is a small number of host companies that are able to accept international internship. We are expecting that these issues could be resolved in cooperation with local companies and municipalities who understand the importance of engineering education for sustainable development of the local communities.

**Acknowledgements**

We are grateful to the students who allowed to be interviewed for this study. We would like to acknowledge the Ministry of Education, Culture, Sports, Science and Technology as the “KOSEN 4.0” Initiative for sponsoring the project of ‘Fostering Practical and Global Engineers by Partnerships with the Regional Community’.

**References**


GLOBAL EDUCATION BASED ON INTERNATIONAL EXCHANGE IN NITKIT

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Abstract

In a rapidly globalizing modern society, we need to promote global education based on international exchange that grows internationally competitive students for education and research. We try to develop our exchange programs to accept an increasing number of foreign students to Japan (inbound) and Japanese students to foreign countries for studying abroad (outbound). Furthermore, we foster talented students capable of working in the international community. The international students are increasing in National Institute of Technology, Kitakyushu College. (abbreviated by NITKIT) The philosophy of education in NITKIT is to foster pioneer-oriented engineers in the international community. We need to improve the international existence in NITKIT which will proceed global manufacturing education. We seek to stimulate international exchange between motivated outstanding foreign students and Japanese students and to construct a school for nurturing international professionals and creating connections, as well as for initiating education to promote intercultural understanding.

In this paper, we will report the international exchange program in NITKIT. We state about overseas affiliated universities. When the foreign students come to the NITKIT, the NITKIT students can get the international perspective by concerning about the international exchange in education contents at present. Through international exchange and cultural experience abroad, the Japanese students can improve learning motivation and get the ability that they have not had so far. They can improve the technical skills which are useful for cultural negotiations, leaderships, communication skills and job hunting. The foreign students and Japanese students can enjoy and practice the good international exchange activities together. NITKIT offers their Internship programs which enable students to gain work experience at either Japanese or foreign companies. This helps students to develop an understanding of work and gain skills for integrating themselves actively into our society.

The NITKIT students face various realistic problems in the world with independence, cooperation and creative attitudes when contacting with foreign students. They have acquired scientific thinking, professional and practical knowledge and world technology. We are practicing global education by accepting both short-term and long-term inbound students. Finally, we discuss that we are able to develop a comprehensively enhancing project and trusted processes to build inbound-outbound relationships in future.

Keywords: International Exchange, Global Education, Internship program, Inbound Exchange, Outbound exchange

1. Introduction

NITKIT philosophy of education is to foster pioneer-oriented engineers. One of the objectives is to acquire international awareness to gain trust and respect in the international community. The international students are increasing in NITKIT. It is important that NITKIT which offers global manufacturing education, need to enhance the position in the international community.

It's necessary that we help the student to get the international perspective by experiencing the international exchange. The students with international exchange and cultural experience abroad, improve learning motivation and get the international empowerment. They can improve various kinds of skills, which are useful for cultural negotiations, leaderships and communication skills and job hunting. There are many foreign students in NITKIT and they help each other to study. The foreign students and Japanese students can enjoy the studying process together and practice the good international exchange activities.

There are many educational environments to study abroad(outbound) among agreement schools (cf. chapter 2) and experience student exchange(inbound) with foreign students in NITKIT. (chapter 4.2) By cooperating with domestic and overseas institutions or organizations, NITKIT can provide international education.
2. Agreement schools

2.1 Overseas Affiliated Universities

It is indispensable to comply with MOU (Memorandum Of Understanding) for ensuring the safety and agreements of students and teachers in another countries. NITKIT has cooperative agreements with overseas affiliated Universities in the world. (cf. Table 2.1) A number of students go abroad every year to make research and pursue active academic exchanges.

<table>
<thead>
<tr>
<th>Year</th>
<th>Country</th>
<th>School</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017</td>
<td>Germany</td>
<td>Hochschule Esslingen</td>
</tr>
<tr>
<td>2016</td>
<td>Singapore</td>
<td>Nanyang Polytechnic</td>
</tr>
<tr>
<td>2015</td>
<td>Thailand</td>
<td>King Mongkut’s Institute of Technology Ladkraban</td>
</tr>
<tr>
<td>2010</td>
<td>Korea</td>
<td>Chonbuk National Mechanical Technical High School</td>
</tr>
<tr>
<td>2010</td>
<td>Korea</td>
<td>Chonbuk National University</td>
</tr>
<tr>
<td>1994</td>
<td>China</td>
<td>Yangzhou University</td>
</tr>
</tbody>
</table>

2.2 9 Kosen collaboration Project

In a Project with collaboration with 9 Colleges of National Institute of Technology in Kyushu-Okinawa National institute of technology of Nine colleges (Kitakyushu, Kurume, Ariake, Sasebo, Kumamoto, Oita, Miyakonojo, Kagoshima and Okinawa), we developed a lot of international exchange activities through internship, overseas training. (cf. Table 2.2)

<table>
<thead>
<tr>
<th>Year</th>
<th>Country</th>
<th>Partner University</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>Taiwan</td>
<td>National Taipei University of Technology</td>
</tr>
<tr>
<td>2014</td>
<td>Mongolia</td>
<td>The Mongolian University of Science and Technology</td>
</tr>
<tr>
<td>2014</td>
<td>China</td>
<td>Xiamen University of Technology</td>
</tr>
<tr>
<td>2014</td>
<td>Viet Nam</td>
<td>Hanoi University</td>
</tr>
<tr>
<td>2017</td>
<td>Viet Nam</td>
<td>University of Danang</td>
</tr>
<tr>
<td>2016</td>
<td>Thailand</td>
<td>King Mongkut's University of Technology Thonburi</td>
</tr>
<tr>
<td>2014</td>
<td>Thailand</td>
<td>King Mongkut's University of Technology North Bangkok</td>
</tr>
<tr>
<td>2014</td>
<td>Thailand</td>
<td>Kasetsart University</td>
</tr>
<tr>
<td>2014</td>
<td>Indonesia</td>
<td>Vocational College Universitas Gadjahmada</td>
</tr>
<tr>
<td>2014</td>
<td>Indonesia</td>
<td>Universitas Gadjahmada</td>
</tr>
<tr>
<td>2014</td>
<td>Malaysia</td>
<td>Institute of Technology Petronas SDN BHD</td>
</tr>
</tbody>
</table>

2.3 NITKIT long-term Foreign student

NITKIT accepts foreign students in the 3rd grade every year. The students enroll in 3rd grade in NITKIT after they study Japanese at Japan language schools. (cf. Table 2.3) They live in NITKIT dormitory for three years. They are given Japanese lectures together with Japanese students.

<table>
<thead>
<tr>
<th>Year</th>
<th>Gender</th>
<th>Engineering Course</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017</td>
<td>Male</td>
<td>Robotics and Mechatronics</td>
</tr>
<tr>
<td>2017</td>
<td>Male</td>
<td>Material Chemistry</td>
</tr>
<tr>
<td>2016</td>
<td>Female</td>
<td>Material Chemistry</td>
</tr>
<tr>
<td>2015</td>
<td>Male</td>
<td>Information and Systems</td>
</tr>
<tr>
<td>2015</td>
<td>Female</td>
<td>Material Chemistry</td>
</tr>
</tbody>
</table>

2.4 Research abroad of NITKIT teacher

The teachers of NITKIT go abroad for research activities. (cf. Table 2.4)

<table>
<thead>
<tr>
<th>Period</th>
<th>Country</th>
<th>Engineering Course</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016.5.1-2017.3.31</td>
<td>America</td>
<td>The University of Massachusetts Amherst</td>
</tr>
<tr>
<td>2015.4.1-2016.3.31</td>
<td>HongKong</td>
<td>Hong Kong Vocational Training Council</td>
</tr>
<tr>
<td>2015.8.14-2016.8.7</td>
<td>America</td>
<td>College of William &amp; Mary</td>
</tr>
<tr>
<td>2014.9.21-2015.3.22</td>
<td>Singapore</td>
<td>Republic Polytechnic</td>
</tr>
<tr>
<td>2014.7.1-2015.9.30</td>
<td>America</td>
<td>State University of New York</td>
</tr>
</tbody>
</table>

3. NITKIT student study abroad

3.1 NITKIT Collaboration Project

NITKIT students go abroad for the following study program in Table 3.1

<table>
<thead>
<tr>
<th>Period</th>
<th>Number</th>
<th>School</th>
</tr>
</thead>
<tbody>
<tr>
<td>2018.3.16-3.21</td>
<td>18</td>
<td>Chonbuk National University, Chonbuk National Mechanical Technical High School (Korea)</td>
</tr>
<tr>
<td>2017.3.19-3.24</td>
<td>11</td>
<td>Chonbuk National University, Chonbuk National Mechanical Technical High School (Korea)</td>
</tr>
<tr>
<td>2016.9.1-9.7</td>
<td>5</td>
<td>Chonbuk National University (Korea)</td>
</tr>
<tr>
<td>2016.3.20-3.25</td>
<td>8</td>
<td>Chonbuk National University (Korea)</td>
</tr>
<tr>
<td>English language Training (2016.8.30-9.20)</td>
<td>13</td>
<td>University of Oxford University of Bath (England)</td>
</tr>
<tr>
<td>English language Training (2015.8.17-9.7)</td>
<td>11</td>
<td>University of Oxford University of Bath (England)</td>
</tr>
</tbody>
</table>
3.2 Tobitate! (Leap for Tomorrow) Study Abroad Initiative JAPAN (Outbound)

Ministry of Education, Culture, Sports, Science and Technology (abbreviated by MEXT) started the program called “Tobitate! Study Abroad Initiative JAPAN” for the purpose of breeding Japanese youths who are willing to study overseas by themselves in 2014. The study abroad system offered supports such as the scholarship program by collaboration of government and commercial corporation. (cf. Table 3.2)

Table 3.2. Tobitate! Study Abroad Initiative (Outbound)

<table>
<thead>
<tr>
<th>Period</th>
<th>Outbound School</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016.8.19-2017.5.21</td>
<td>Wabash Valley College (America)</td>
</tr>
<tr>
<td>2016.4.11-2017.3.10</td>
<td>Institute of Chemical Research of Catalonia (Spain)</td>
</tr>
<tr>
<td>2015.4.1-2016.2.29</td>
<td>Chonbuk National University (Korea)</td>
</tr>
<tr>
<td>2015.8.22-2015.9.25</td>
<td>Queens College of The City University of New York (America)</td>
</tr>
</tbody>
</table>

3.3 Japan Student Services Organization (Outbound)

Japan Student Services Organization (JASSO) is an independent administrative institution established under the MEXT. JASSO administers scholarship supports programs for students. Our NITKIT students use this program as shown in the following Table 3.3.

Table 3.3 JASSO (Outbound)

<table>
<thead>
<tr>
<th>Period</th>
<th>Number</th>
<th>School</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017.10.1-2018.2.28</td>
<td>1</td>
<td>Reutlingen University</td>
</tr>
<tr>
<td>2017.09.6-2018.2.28</td>
<td>1</td>
<td>Esslingen University</td>
</tr>
<tr>
<td>2018.3.09-3.30</td>
<td>15</td>
<td>Nanyang Polytechnic (Singapore)</td>
</tr>
<tr>
<td>2018.7.20-9.18</td>
<td>7</td>
<td>Nanyang Polytechnic (Singapore)</td>
</tr>
<tr>
<td>2017.3.02-3.31</td>
<td>4</td>
<td>Nanyang Polytechnic (Singapore)</td>
</tr>
<tr>
<td>2016.8.23-9.23</td>
<td>4</td>
<td>Nanyang Polytechnic (Singapore)</td>
</tr>
</tbody>
</table>

3.4 9 Kosen Collaboration Project (cf. chapter 3.2)

Table 3.4 9 Kosen Collaboration Project

<table>
<thead>
<tr>
<th>Period</th>
<th>Number</th>
<th>School</th>
</tr>
</thead>
<tbody>
<tr>
<td>English Program</td>
<td>1</td>
<td>Hanoi University (Viet nam)</td>
</tr>
<tr>
<td>2017.9.17-9.27</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learn Technology in English Program</td>
<td>1</td>
<td>Kasetsart University (Thailand)</td>
</tr>
<tr>
<td>2017.8.21-9.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Technical Challenge (2017.8.21-8.29)</td>
<td>1</td>
<td>Hong Kong Vocational Training Council (China)</td>
</tr>
<tr>
<td>English Camp (2017.8.13-8.27)</td>
<td>1</td>
<td>Singapore Polytechnic (Singapore)</td>
</tr>
<tr>
<td>Summer Program (2016.8.15-8.24)</td>
<td>1</td>
<td>National Taipei University of Technology (Taiwan)</td>
</tr>
<tr>
<td>Spring Program (2016.3.16-3.27)</td>
<td>1</td>
<td>National Taipei University of Technology (Taiwan)</td>
</tr>
<tr>
<td>2017.1.16-1.20</td>
<td>4</td>
<td>Institute of Technology</td>
</tr>
</tbody>
</table>

3.5 International Symposium

The objective of International Seminar on Technology for Sustainability is to foster the global engineers with the leadership.

Table 3.5 International Seminar

<table>
<thead>
<tr>
<th>Period</th>
<th>School</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017.8.20-8.27 ISTS2017</td>
<td>Turku University of Applied Sciences (Finland)</td>
</tr>
<tr>
<td>2016.10.5-10.12 ISTS2016</td>
<td>Vocational College Universitas Gadjahmada (Malaysia)</td>
</tr>
<tr>
<td>2015.8.4-8.6 ISTS2015</td>
<td>Universiti Teknologi MARA (Malaysia)</td>
</tr>
</tbody>
</table>

3.6 Another Collaboration Project

Table 3.6 Another Collaboration Project

<table>
<thead>
<tr>
<th>Period</th>
<th>Number</th>
<th>School</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workshop (2017.8.7-8.22)</td>
<td>1</td>
<td>Yangzhou University (China)</td>
</tr>
<tr>
<td>Kitakyushu Water Works(2017.8.7-8.22)</td>
<td>1</td>
<td>Phnom Penh Capital Hall (Cambodia)</td>
</tr>
<tr>
<td>Summer School (2017.8.25-8.28)</td>
<td>1</td>
<td>University of California, Berkeley etc. (USA)</td>
</tr>
<tr>
<td>Global Engineering Foster Program (2017.8.28-9.1)</td>
<td>1</td>
<td>Toyohashi University Sains Malaysia Technology Collaborat. (Malaysia)</td>
</tr>
<tr>
<td>2017.3.5-3.9 Student Exchange</td>
<td>2</td>
<td>Chulalongkorn University, King Mongkut's University Khon Kaen University, etc (Thailand)</td>
</tr>
</tbody>
</table>
4. Foreign Student Exchange by Inbound

4.1 Japan Student Services Organization (Inbound)

Table 4.1 Japan Student Services Organization

<table>
<thead>
<tr>
<th>Period</th>
<th>Number</th>
<th>School</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016.9.19-2017.1.20</td>
<td>1</td>
<td>Nanyang Polytechnic</td>
</tr>
<tr>
<td>2016.9.16-12.14</td>
<td>2</td>
<td>(Singapore)</td>
</tr>
</tbody>
</table>

4.2 Short-term inbound international exchange

Table 4.2 Short-term inbound international exchange

<table>
<thead>
<tr>
<th>Period</th>
<th>Number</th>
<th>School</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016.9.18-9.24</td>
<td>9</td>
<td>Vocational Training Council, Hong Kong</td>
</tr>
<tr>
<td>2016.10.16-10.25</td>
<td>6</td>
<td>Vocational College Universitas Gadjahmada</td>
</tr>
<tr>
<td>2016.1.18-2.27</td>
<td>3</td>
<td>Universitas Gadjah Mada</td>
</tr>
<tr>
<td>2017.3.5-3.12</td>
<td>4</td>
<td>King Mongkut’s Institute of Technology Ladkrabang</td>
</tr>
<tr>
<td>2016.10.16-10.25</td>
<td>2</td>
<td>King Mongkut’s Institute of Technology Ladkrabang</td>
</tr>
<tr>
<td>2017.3.5-3.12</td>
<td>4</td>
<td>Kasetsart University</td>
</tr>
<tr>
<td>2017.3.5-3.12</td>
<td>5</td>
<td>Nanyang Polytechnic</td>
</tr>
</tbody>
</table>

Table 4.3 Short-term international exchange

<table>
<thead>
<tr>
<th>Period</th>
<th>Number</th>
<th>School</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016.4.10-7.10</td>
<td>2</td>
<td>Nanyang Polytechnic</td>
</tr>
<tr>
<td>2015.9.29-12.18</td>
<td>4</td>
<td>Nanyang Polytechnic</td>
</tr>
<tr>
<td>2015.8.22-11.30</td>
<td>1</td>
<td>Nanyang Polytechnic</td>
</tr>
<tr>
<td>2015.4.13-7.2</td>
<td>4</td>
<td>Nanyang Polytechnic</td>
</tr>
<tr>
<td>2017.1.16-2017.3.10</td>
<td>2</td>
<td>Temasek Polytechnic</td>
</tr>
<tr>
<td>2015.9.28-2016.12.20</td>
<td>2</td>
<td>Temasek Polytechnic</td>
</tr>
<tr>
<td>2015.9.22-2016.2.6</td>
<td>2</td>
<td>Republic Polytechnic</td>
</tr>
<tr>
<td>2016.6.1-8.1</td>
<td>3</td>
<td>King Mongkut’s University of Technology Ladkrabang, Kasetsart University</td>
</tr>
<tr>
<td>2015.6.1-7.31</td>
<td>8</td>
<td>King Mongkut’s University of Technology Ladkrabang, Kasetsart University</td>
</tr>
<tr>
<td>2016.10.16-12.10</td>
<td>6</td>
<td>Kasetsart University</td>
</tr>
<tr>
<td>2016.6.1-8.1</td>
<td>6</td>
<td>Kasetsart University</td>
</tr>
<tr>
<td>2015.6.1-8.1</td>
<td>3</td>
<td>Kasetsart University</td>
</tr>
</tbody>
</table>

5. Internship (9 Kosen Collaboration Project)

The number of the students per technical college is about 1000. In the internship, we cooperate with the Kyushu Economic Federation with about 900 member companies. In the overseas training program, the school has acceptable companies of the overseas internship. (cf. Table 5.1) Through the international exchanges and overseas training, we will strengthen the relationships with Asian countries by utilizing the results of exchanges between 9 colleges and higher education institutions in Asian countries.

It is important to experience real training techniques based on a basic theory and knowledge. The international internship study gives the youths extremely effective techniques. The students acquire all of these valuable skills such as intercultural competency, multicultural work, working experience, independence, flexibility and more.

Table 5.1 9 Kosen Collaboration Internship

<table>
<thead>
<tr>
<th>Period</th>
<th>Number</th>
<th>School</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016.7.28-8.20</td>
<td>1</td>
<td>Queens College of The City University of New York</td>
</tr>
<tr>
<td>2015.6.25-8.4</td>
<td>1</td>
<td>Liberty High School</td>
</tr>
</tbody>
</table>

6. Long-Term Factory Visit of our course class

For the purpose of understanding different cultures, our students in NITKIT interexchange with the overseas schools in September every year. It is a golden opportunity that the Japanese students visit the foreign country, and interchange with the foreign students, and visit to facilities and make presentation about NITKIT, and experience the different cultures, and grow up by themselves.
Table 6.1: Long-Term Factory Visit

<table>
<thead>
<tr>
<th>Year</th>
<th>Number</th>
<th>Visiting Place</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017.9.26-9.29</td>
<td>39</td>
<td>The Hong Kong Institute of Vocational Education etc.</td>
</tr>
<tr>
<td>2017.9.26-9.30</td>
<td>38</td>
<td>Temasek Polytechnic, The NEWater Visitor Centre, Marina Barrage</td>
</tr>
<tr>
<td>2016.9.27-10.1</td>
<td>41</td>
<td>Temasek Polytechnic, The NEWater Visitor Centre, Marina Barrage</td>
</tr>
<tr>
<td>2015.10.27-10.31</td>
<td>45</td>
<td>National Taipei University of Technology, Taiwan Hirata Corporation</td>
</tr>
<tr>
<td>2015.10.27-10.30</td>
<td>39</td>
<td>National Taipei University of Technology, Taiwan TAKISAWA Technology Co., Ltd.</td>
</tr>
</tbody>
</table>

7 OUR TP internship

We have started a cultural exchange plan by the students for the NITKIT and Polytechnic Schools in Singapore since 2006. We have developed a higher exchange level.

1) The students in Singapore study Japanese in our NITKIT and understand advanced techniques such as information security.
2) They study a research technology such as steganography.
3) They make cultural exchange with Japanese students.
4) They acquire the communication skills in Japanese and English with Japanese students.
5) They visit various factories in Kitakyushu.

We accepted two students in Temasek Polytechnic from 2016 through 2018. Advanced course students of NITKIT supported the foreign students. They have had poster presentations in their research fields in the international conference.

8. Our Sakura Science Project 2017

We had an exchange program with 10 students in Temasek Polytechnic school by Sakura science project. Kitakyushu has a long history of industry which is representative of Japan. There are industries that utilize advanced technologies such as IoT (Internet of Things) / M2M (Machine to Machine), robotic new strategy, the fourth industrial revolution (Industrie 4.0), FinTech and etc. The students from Singapore can learn about research results at NITKIT and universities, advanced technologies and companies and factories, and understand how Japanese technology contributes to the development of local communities.

The objective of this program is that the Foreign students and NITKIT students acquire the Robot skills, and Echology skills, and international communication skills. The participating TP students study some computer knowledge in school of Informatics & IT and then take part in a workshop with familiar contents. The TP and NITKIT students speak English in the workshop. (cf. Fig 8.1) The students visited research equipments and NITKIT facilities. The students had technical exchanges by using their research presentation. The NITKIT students and TP students understood the academic research and got interested in the problem. They also learn about their educations and the cultures each other.

Fig 8.1 Technical workshop

The students visited Yawata Works (Nippon Steel & Sumitomo Metal). They observed a blast furnace factory, the hot rolling factory and learned about the process of the history and the iron manufacture. They could deepen the understanding of the industrial area in Kitakyushu. (cf. Fig 8.2)

Fig 8.2 Factory visit

They had Japanese traditional cultural exchange. They played Japanese traditional musical instruments such as Koto and shakuhachi (PVC pipe). They wore Japanese traditional dress such as yukata. They enjoyed Japanese traditional cultural exchange. (cf. Fig 8.3)
They had cultural exchange. They did sightseeing at Mojiko Retro district. They were able to learn about the history of Moji Port which opened in the early Meiji era, the building which was built from the Meiji to the Taisho era by observing the strait dramaship, old monarchy customs, old gate Mitsui club, Idemitsu Museum etc.

9. Discussions

Living in the world with the social change such as declining birthrate and intensifying competition with foreign countries, it is essential for National Institute of Technology KOSEN to develop global and innovational engineers who are responsible for reforming social change.

It is necessary for the KOSEN to foster engineers who are practical, creative with international perspective and responsible for the enterprises and social community.

It is necessary to advance globalization with international community and overseas support in cooperation with society and companies.

In future international collaborative exchanges, engineer’s education with global partnership, in addition to developmental relations such as international students’ acceptance, exchange process, overseas relationship is required.

10. Conclusions

We have reported the international Exchange programs in the NITKIT. International exchange education needs to comply with Memorandum of Understanding (MOU) and collaborating with overseas schools and companies.

Through the international exchange programs, NITKIT fostered a lot of international engineers with global minds, creative thinking, high communication and cooperation abilities. These international talents are competent for the rapid development of our society.

NITKIT is considering the construction of global center, aiming to train more and more practical talents of advanced technologies. In the near future, we are able to develop a comprehensively enhancing project and trusted processes to build inbound-outbound relationships.
INTERNATIONAL COOPERATIVE ENGINEERING EDUCATION BETWEEN JAPANESE AND MONGOLIAN KOSENS IN ELECTRICAL AND ELECTRONIC ENGINEERING

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Abstract

Among about 150 Mongolian people who had studied at the KOSEN colleges in Japan for the past 20 years, there was an increasing strong aspiration to set up Japanese-style KOSEN Colleges in Mongolia. Receiving strong backing from former Minister of Education and Science of Mongolia, Mr. Luvsannyam Gantumur, who studied abroad at Sendai KOSEN in Japan, they established Japanese-style KOSEN Colleges, “Institute of Engineering and Technology (IET), Mongol KOSEN College of Technology” in 2013, followed by “Mongolian University of Science and Technology (MUST) KOSEN College of Technology” and “New Mongol College of Technology” in 2014. To extend Japanese-style KOSEN education further throughout Mongolia, it seems to be critical to raise up level of education of the present KOSEN Colleges in Mongolia. This paper reports a project to improve the education level in the Department of Electrical and Electronic Engineering at the KOSEN Colleges in Mongolia. From 14th January to 18th January 2018, eight teachers who belong to the Department of Electrical and Electronic Engineering at the KOSEN Colleges in Mongolia visited Japan for a training workshop at Nagaoka KOSEN. This training workshop aimed to deepen their understanding about research facilities, practical education using experiments, and education system of Japanese KOSEN. From 4th March to 11th March 2018, Professor Susumu Nakamura at Nagaoka KOSEN, Associate Professor Masaaki Yoshida at Hachinohe KOSEN and Associated Professor Takanobu Maeda at Sasebo KOSEN were dispatched to MUST KOSEN College of Technology in Mongolia. Two students who are majoring electrical and electronic systems engineering at Nagaoka KOSEN were also dispatched to MUST KOSEN College of Technology as teaching assistants. During their stay in Mongolia, they taught how to use an electronic circuit simulator, kits of electric circuits and an operational amplifier, and a single-chip microcontroller to Mongolian teachers.

Keywords: International Cooperation, Engineering Education, Electrical and Electronic Engineering, Japanese KOSEN, Mongolian KOSEN

1. Introduction

The number of students in higher educational institutes in Mongolia is increasing based on the needs of higher education since 2000. The number of students in the academic year 2015 to 2016 has increased to about 65% from the academic year 2002 to 2003. The proportion of the students who have entered universities to all graduates from full-time senior high schools in the academic year 2016 to 2017 was 75.6%. The proportions of the students who have chosen science or engineering majors were about 5% or 16.3% respectively, which shows just a small increase compared with data in 2012.

On the other hand, there is a gap between the types of human resources required by companies in industrial area in Mongolia and the graduates educated by Mongolian present higher education institutes. This is due to the situation such that current educational programs focus on theoretical learning mainly through lectures and most students start working without adequate ability of application or problem solving which are supposed to be fostered through experiment or laboratory work.

Among about 150 Mongolian people who had studied at the KOSEN colleges in Japan for the past 20 years, there was an increasing strong aspiration to set up Japanese-style KOSEN Colleges in Mongolia. In 2009, they formed a general incorporated association “Society for Establishment of Mongolia KOSEN” in cooperation with people who are involved in KOSEN education in Japan. Later, receiving strong backing from former Minister of Education and Science of Mongolia, Mr.
Luvsannyam Gantumur, who studied abroad at Sendai KOSEN in Japan, they established “Institute of Engineering and Technology (IET), Mongol KOSEN College of Technology” in 2013, followed by “Mongolian University of Science and Technology (MUST) KOSEN College of Technology” and “New Mongol KOSEN College of Technology” in 2014.

In 2013, IET, Mongol KOSEN College of Technology, also known as “Mongol KOSEN”, was established as a school of IET. This college is managed under Mr. Munkh-Ochir Sergelen, Principal of Mongol College of Technology and President of IET, who have experience of studying in Japan. IET, Mongol KOSEN College of Technology has four departments: Construction Engineering, Mechanical Engineering, Electrical and Electronic Engineering, and Biological Engineering.

In 2014, MUST KOSEN College of Technology was established under supervision of Mr. Ganbayar Aleksei, who has previous experience of studying abroad at Tokyo KOSEN in Japan, as ninth school belonging to MUST. MUST KOSEN College of Technology has three departments: Electrical and Electronic Engineering, Civil and Architecture Engineering, and Mechanical Engineering.

A private school corporation, the New Mongol College of Technology was founded in 2014. The New Mongolian Institute is composed of elementary school to university. New Mongol College of Technology was operated under Principal Buyangalgar who studied abroad at Sasebo KOSEN in Japan. New Mongol College of Technology has four departments: Civil Engineering and Architecture, Electrical and Electronics Engineering, Mechanical Engineering, and Chemical Engineering.

National Institute of Technology (NIT), Nagaoka College and Sasebo College were established in 1962, followed by Hachinohe College in 1963, under the Ministry of Education (current Ministry of Education, Culture, Sports, Science and Technology). Based on the Japanese Government’s policy, all 51 National Colleges (55 Campuses) including Nagaoka, Sasebo and Hachinohe Colleges were incorporated as a new single legal entity in 2004 and are now under the umbrella of the National Institute of Technology, Japan. However, each college maintains its independent authority. College of Technology under the National Institute of Technology is popularly called KOSEN.

2. International Cooperative Engineering Education

In order to improve the education level of the present three KOSEN colleges in Mongolia, international cooperative engineering education between Japanese and Mongolian KOSENS was conducted. In this paper, we report the educational training workshops in the Department of Electrical and Electronic Engineering at the KOSEN Colleges in Mongolia.

2.1 Outgoing Program from 23rd October to 27th October 2017

From 23rd October to 27th October 2017, Dr. Susumu Nakamura, a professor of the Department of Electrical and Electronic Systems Engineering at Nagaoka KOSEN, was dispatched to MUST KOSEN College of Technology in Mongolia. During his stay in Mongolia, he taught how to assemble electric circuits using digital ICs and a breadboard to the Mongolian teachers who belong to the Department of Electrical and Electronic Engineering at the KOSEN Colleges in Mongolia. Figure 1 shows the Mongolian teachers who participated in the circuit assembly workshop.

![Figure 1 Mongolian teachers who participated in the circuit assembly workshop.](image)

As teaching material for a course of workshop, “Have Fun with Kits! Electric Circuits, Digital Circuits Edition Vol.1 and Vol.2” produced by ADWIN Corporation were used. These electric kits are designed to be provided to students studying electronics and having interest to electronics, so that they can recognize by themselves through hands-on exercise what they need to learn and understand. These electric kits are useful for science teachers. Teachers are easy to think how to teach electronics to their students effectively using these kits. For this reason, these electric kits were chosen as the teaching material. For assembling the digital circuits, at first, trainees should draw wires to make some connections between each components and/or devices in the drawing of breadboard according to the schematic diagram. Then the trainees start assembly of the circuit, and after that, they confirm its function. As shown in Figure 2, the Mongolian teachers were seriously working on the electronic circuit assembly. The following digital circuits were assembled:

1. NOT logic circuit
2. NOT logic circuit using a variable resistor
3. Multivibrator circuit using NOT logic gates
4. Logic circuit using NAND gates
5. Logic circuit using NOR gates
6. SR Flip-Flop circuit
7. Counter circuit using D-Flip-Flop devices
8. 1-digit BCD Counter
9. A circuit to blink an LED using an NE555

![Figure 2. The Mongolian teachers were seriously working on the electronic circuit assembly.](image)
2.2 Incoming Program from 14th January to 18th January 2018

From 14th January to 18th January 2018, eight Mongolian teachers who belong to the Department of Electrical and Electronic Engineering at the KOSEN Colleges in Mongolia visited Japan for a training workshop at Nagaoka KOSEN. This training workshop aimed to deepen their understanding about research facilities, practical education using experiments, and education system of Japanese KOSEN. During their stay in Nagaoka, they got the following experiments on power electronics:

(i) Control of DC motor
(ii) Control of squirrel-cage induction motor
(iii) Experiment on solar power generation
(iv) Discharge phenomenon in air
(v) Frequency control by three-phase inverter
(vi) AC control by SCR

The power electronics is the application of solid-state electronics to the control and conversion of electric power. In modern systems, the conversion is performed with semiconductor switching devices such as diodes, thyristors and transistors. AC/DC converter (rectifier) is the most typical power electronics device found in many consumer electronic devices. As mentioned above, the power electronics play an important role in modern power and energy control technologies. Therefore, the power electronics needs to be taught in Mongolian KOSEN. Figure 3 shows a lecture on the control of DC motor and Figure 4 shows experiment on the solar power generation.

During the Mongolian teachers stayed in Nagaoka, they visited a company, WEST Co., Ltd., to understand the industry of Nagaoka area. West Co., Ltd. is a small company, but has unique technology to make fine powder from cereals such as rice and buckwheat. WEST Co., Ltd. produced world’s first water cooled stone milling machine. Figure 5 shows factory tour at WEST Co., Ltd.

2.3 Outgoing program from 4th March to 11th March 2018

From 4th March to 11th March 2018, Dr. Susumu Nakamura, a professor of the Department of Electrical and Electronic Systems Engineering at Nagaoka KOSEN, Dr. Masaaki Yoshida, an Associate Professor of the Department of Liberal Arts and Engineering Sciences at Hachinohe KOSEN and Mr. Takanobu Maeda, an Associate Professor of the Department of
Control Engineering at Sasebo KOSEN were dispatched to MUST KOSEN College of Technology in Mongolia. Two students who are majoring electrical and electronic systems engineering at Nagaoka KOSEN were also dispatched to MUST KOSEN College of Technology as teaching assistants. The teaching materials they brought were an electronic circuit simulator, kits of electric circuits and an operational amplifier, and a single-chip microcontroller of ATmega328.

The training workshop on the electronic circuit simulator was a request from the Mongolian teachers. LTspice XVII was chosen as the electronic circuit simulator. LTspice XVII is node-unlimited and third-party models can be imported. Circuit simulations based on transient, AC, noise and DC analysis can be plotted as well as Fourier analysis. LTspice XVII also supports simple logic gate simulation. As shown in Figure 6, the Mongolian teachers discussed about how to use the electronic circuit simulator. During this workshop, the following simulations on the electronic circuits were conducted:

(i) RC low pass filter
  - Drawing the circuit diagram with the editor
  - Changing part values
  - Time domain simulation

(ii) Rectifier
  - Simple rectifier without transformer
  - One pulse rectifier with transformer
  - Two pulse rectifier with transformer

(iii) Transistor circuit
  - One stage amplifier
  - Two stage broadband amplifier with feedback

After LTspice XVII training workshop, “Have Fun with Kits! Electric Circuits, Basic Edition Vol.1 and Vol.2” produced by ADWIN Corporation were used as the teaching material. Assembling electric circuits using these kits were as follows:

(i) Make LED light ON
(ii) Change connection of LED reverse
(iii) Use variable resistors
(iv) Parallel connection circuit
(v) Diode circuit; rectification circuit
(vi) Use transistors; DC motor control 1, 2, 3

As mentioned previously, two students who are majoring electrical and electronic systems engineering at Nagaoka KOSEN were dispatched to MUST KOSEN College of Technology as teaching assistants. They made presentations on their graduation researches to Mongolian students during the workshop break time as shown in Figure 7. Mongolian students will be fifth-year class in next academic year and they will conduct final year research. Therefore, the Mongolian students were seriously listening to the presentations of Nagaoka KOSEN students.

After assembling the Electric Circuits, Basic Edition Vol.1 and Vol.2, “Have Fun with Kits! Op-amp Introductory Edition” produced by ADWIN Corporation were used as the teaching material. The Op-amp means a word “operational amplifier”. The word “operational” in the name refers to mathematical operations such as addition, subtraction, differentiation, integration, etc., since Op-amps are direct current amplifiers capable of performing such tasks. Although Op-amps are not normally seen, they are actually widely used in appliances with analog circuits that everybody should have. They can be found, for example, in mobile telephones, personal computers, audio players, headphone amplifiers, sensor circuits, and measuring devices. Figure 8 shows that the Mongolian teachers observed signals from the Op-amp circuit using analog oscilloscope. During this training workshop, assembling circuits using Op-amp kits were as follows:

(i) Inverting amplifier circuit
(ii) Non-inverting amplifier circuit
(iii) Adder circuit
(iv) Subtractor circuit
(v) Voltage follower circuit
(vi) Comparator circuit

Figure 6 Discussion about the electronic circuit using the circuit simulator, LTspice XVII.

Figure 7 Advanced course student’s presentation on graduation research.
As the last training workshop, the Mongolian teachers tried to modify “Bontenmaru” robot using the single-chip microcontroller, ATmega328. Bontenmaru is an autonomous two-wheel drive robot that can be run with a simple program for elementary and junior high school students. Although the original Bontenmaru uses a PIC microcontroller as a computing device, the Mongolian teachers tried to replace the PIC microcontroller with the ATmega328 microcontroller. Because most of the Mongolian teachers who participated in this training workshop serve as robot club advisors, they were interested in using the ATmega328 microcontroller. Figure 9 shows control of “Bontenmaru” using the ATmega328 microcontroller.

At the meeting of exchange ideas after the training workshops, the Mongolian teachers mentioned that the cooperative engineering training program gave them a rare opportunity to interact with Japanese KOSEN teachers and to obtain very significant educational benefits, such as improving communications skills and stimulating motivation for learning new technology. Figure 10 shows Japanese and Mongolian KOSEN teachers and Nagaoka KOSEN students who participated in the training workshops.

3. Conclusions

In this project, the workshops for implementing the Japanese KOSEN educational system in Mongolian KOSEN were conducted. It is confirmed that fostering engineers in both Japanese and Mongolian KOSENs is very meaningful and KOSEN students will bridge two countries.

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A CROSS CULTURAL LEARNING EXPERIENCE FROM URBAN FARMING

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**Abstract**

Singapore’s Smart initiative journey on ‘E3A’: Everyone, Everything, Everywhere, All the time started few years back to enable greater connectivity, better situational awareness through data collection and efficient sharing of data collection using sensors. Urban farming is one of the Singapore’s Smart Nation initiative to let urban farms to reach their full potential of health, technology, sustainability and profit.

In this paper, the authors share their experiences in bringing student leaders from two ASEAN countries to work together on an urban farming project using the Temasek Foundation International Specialist’s Community Action and Leadership Exchange (TFI SCALE) platform. The TFI SCALE exchange program gives tertiary students an opportunity to collaborate and identify common social issues in the community and design solutions that extend across national and cultural boundaries. Authors also share the knowledge gained by students to demonstrate their ideas in urban farming that may lead to set up a business case studies for a sustainable and profitable food chain. In addition authors share the challenges faced by the students during the cross-cultural exchange programme.

Authors used Kolb’s Experiential Learning model theory as a reference for this project to demonstrate and facilitate the learning cycle. Authors opined that the TFI SCALE program is a good platform that can bring many positive outcomes for creating future leaders through social, technical, and cross-cultural communication.

**Key words:** Smart Nation, TFI SCALE, cross-culture, urban farming, Kolb Experiential Learning, IoT.

**Introduction**

TFI SCALE is a student leadership program that is specially designed for student leaders from universities and polytechnics. Its goal is to build bridges between students across ASEAN countries.

In this paper, the authors share their experience on an urban farming project leveraging on the TFI SCALE IV programme, involving Singapore and Indonesian students. This program provided a framework that allowed student leaders of a Polytechnic in Singapore and two Indonesian Institutions, to collaborate effectively.

**Cultural Diversity**

Cultural diversity is a form of appreciating the differences in individuals. Diverse cultural perspectives can inspire creativity and innovation that leads to opportunities for both personal and professional growth. However, misunderstandings and misinterpretations could exist due to cultural differences in terms of working styles, differing professional etiquette, and including conversational habits.

Being a member of ASEAN, Singapore is in a region with multi-race and multi-culture as its main backdrop. While Singapore takes pride in having multiculturalism in its society at large, it is only a small part of a more diverse mix of societies in the ASEAN region. Therefore, outward exposure remains a key focus to achieve mutual understanding.

Open communications and interactions will help in dampening cultural friction. Along with this line of thought, the TFI SCALE programme provides a platform to bring two distinctive groups of students to work together, with the goal to encourage mutual understanding and to forge better appreciation among the participants.

**Motivation**

*Rising challenge of food scarcity and security in Singapore*

Due to Singapore’s land paucity, only 1% of land is used for agriculture (The World Factbook 2018). Ultimately, agriculture appears distant from an urbanised Based on Figure 1, Singapore’s food security becomes a major threat as the country is dependent on international markets for food supply. Moreover, the demand for food over the next decade is expected to increase by 1.1 percent annually (2), as the global food productivity gains continue to decline.
Figure 1: Major food importers for Singapore

Domestic ramifications, such as price increases in food imports and export bans by food suppliers, are major threats to food scarcity. Rapid increase in urban population and resource constraints on the global food system in the future are major threats that can ultimately lead to higher food prices in Singapore.

Food sustainability and food security are impending issues due to the threat of decreased food supply from agricultural countries due to changes in climate, lowering of water supply, pest manifestation etc. A 10 percent decrease in agricultural yield is forecasted due to climate change. Future resource constraints on the global food system present a critical need for alternative farming methods. A study led by the Agri-food and Veterinary Authority (AVA) of Singapore reiterated challenges in food source diversification, internationalization, and local production. “The AVA is working closely with International Enterprise (IE) Singapore to identify multiple sources for some of Singapore’s main food items” (Paul Teng and Margarita Escaler 2010 Page 11).

Urban Farming – a budding initiative

There is a trend in urban farming taking place in major cities around the world (Urban Farming: the future of Agriculture n.d.). One of the contributing factors is the scarcity of land where space is a luxury. Singapore imports over 90% of the food consumed in the country (Paul Teng and Margarita Escaler 2010 Page 11).

Singapore, said to be one of the most digitally savvy countries (Global Information Technology Report 2016), is receptive towards technology adoption. With the advancement of technologies and the emergence of various IoT (Internet of Things) solutions, many innovative urban farming ideas have been conceptualized and tested. Applications built using IoT platform help farmers to address multiple agricultural needs, such as gathering data about plants, planting field conditions for better resource management, using GPS signals for monitoring weather information and using sensors and drones to monitor the growth of the plants (Urban Farming 2018). On the other hand, Indonesia has rich experience in the agricultural sector. This pairing presented good opportunities for knowledge exchange and mutual learning.

Methodology

Active learning has been suggested to achieve more concrete learning outcome (Keeton, M. and Tate, P. 1978) as it involves direct involvement, outside of the classroom. With that, the authors have adopted experiential learning, which is described in Figure 2, based on Kolb’s learning model (Kolb, David 1984).

In accordance to Kolb’s model, 4 phases, Concrete Experience, Reflective Observation, Abstract Conceptualization and Active Experimentation have been planned and implemented

Figure 2: Kolb’s Experiential Learning Cycle

Phase I – Concrete Experience

A group of 20 students from a polytechnic in Singapore and 20 students from two Indonesian Institutions, were engaged in a three-week immersion program. During this program, they participated in different activities based in Singapore, including visiting historical sites, understanding the culture, and experiencing the country’s social life. Students participated in various team activities such as the Adventure Learning Programme (ALP) and the Problem Based Learning (PBL) pedagogy. This fostered good working relationships between the students from both countries, enabling students to identify and overcome the cultural barriers. For most of the Indonesian students, this program was remarkable since it was their first visit abroad.

In phase I, both Singapore and Indonesian students exchanged their cross-cultural experiences between the two countries. The Indonesian students shared their social life and their culture. The main source of income for most of the families is traditional farming. They shared the two main types
of traditional farming. The first is traditional subsistence farming, where families work together to plant and harvest crops to support their family with little left over to sell. The second method is traditional intensive farming, in which farmers increase their yield by increasing human and draft-animal labour, and using animal manure as fertilizers to obtain higher crop yield. They also shared on the consequences of setting forest and plantations on fire.

On the other hand, Singapore being an urban country, “farming” seems to be a foreign concept for most of the Singapore students, because 90% of the food is imported from other countries Paul Teng and Margarita Escaler (2010). As a part of Singapore’s Smart Nation initiative, more urban farms, rooftop gardens are taking root in Singapore. “Such features have been gaining popularity in our urban landscape, as many Singaporeans have a keen interest in farming and gardening” (Wendy Wong 2017). During their discussions, one of the topics that captivated everyone’s interest was the rising challenge of food scarcity and food security in Singapore. Root cause analysis was used to recognise the root causes of Singapore’s food scarcity and security and to develop efficient interventions to address the same.

**Phase II – Reflective Observation**

Both Singaporean and Indonesian students reflected on the root causes and the new initiatives taken by Singapore to prevent food scarcity in the future. They decided to explore on the new techniques of using urban farming to increase local production in Singapore. Being a small country, land scarcity is one of the major constraints for conventional farming at Singapore Paul Teng and Margarita Escaler (2010). Urban farming being one of the Singapore’s Smart Nation initiative to let urban farms to reach their full potential of health, technology, sustainability and profit. Urban farming in Singapore has moved into a new, high-tech phase to grow pesticide free garden-fresh edibles through innovative methods (Fresh Ideas for City Farms 2017). For the Indonesian students, it is new and Singapore students shared on the initiatives taken by Singapore, as a nationwide gardening initiative that enabled more than 1,000 community gardening groups to come together and grow edibles in community gardens.

Urban farming has become more popular for the children and the elderly to spend their time in a more meaningful way. It also builds on the “Go Green” technology. This is an eye-opening session for Indonesian students and it motivated them to explore further on different ways on applying at their home ground.

For Phase II, the aim was to explore more on urban farming. Field trips were organised to the different places (Agricultural farms, Fish farms, Hydro and Aquaponics farms, Community centre with Hydroponics system) to create awareness and understanding on the use of urban farming from different perspectives.

**Phase III – Abstract Conceptualization**

During site visits, students were engaged in fun activities whilst being introduced to the basic skills in using simple farming equipment. It was really an eye-opening for Singapore students because this was their first hand-on experience to farming. The field trip (Figures 3 and 5) and sharing session at farms was focussed in setting up urban farming in Singapore by making use of the resources across countries. The motivational talk created an awareness to overcome the cross-cultural differences and the importance of setting up urban farming to overcome food scarcity in Singapore.
Reflections and sharing sessions from the site visits helped the students gain more knowledge towards urban farming based on different scales. Based on the sharing session, the team managed to identify the different methods of urban farming that include indoor gardening, container gardening, community gardening and rooftop gardens (Urban Farming: the future of Agriculture (n.d.)).

To conclude, students had a fruitful discussion that lead to an innovative method to build a prototype for Indoor Gardening using Hydroponics and Aquaponics systems that uses smart devices monitor and control the growth of plants using sensors. It is basically growing healthy plants without the use of a traditional soil-medium by using a nutrient like mineral rich water solution instead. It needs nutrients, water, and sunlight to grow.

Benefits of using Aquaponics over Hydroponics

The only difference between these two is, hydroponics revolves around a sterile environment whereas aquaponics embraces an all micro-organism approach to play an important part in the growing process. One advantage of aquaponics is it tends to have less diseases and pest problems because it eliminates the use of pesticides. On the other hand, hydroponics might use toxic chemicals to grow plants and to raise harvest.

To conclude, students had a fruitful discussion that lead to an innovative method to build a prototype for Indoor Gardening using Hydroponics and Aquaponics systems that uses smart devices monitor and control the growth of plants using sensors. It is basically growing healthy plants without the use of a traditional soil-medium by using a nutrient like mineral rich water solution instead. It needs nutrients, water, and sunlight to grow.

Smart Nation Initiative on Championing Urban Farming

To overcome the land scarcity, Singapore’s residential and commercial rooftops could be transformed into “sky farms” to increase the productivity of fresh vegetable, flowers and fruits using cutting-edge farming technology. Singapore being one of the global leader for hydroponic technologies, and together smart nation initiatives, urban farming has moved into a new high-tech phase. Hydroponics and Aquaponics systems allow plants to grow up to 50% faster than in soil and are healthier.

The next challenge they faced is choosing a feasible home-based hydroponics system. Based on the research there are six types of hydroponics system. All the six types of hydroponics systems (Drip System, Ebb-Flow, NFT, Water culture, Aeroponics and Wick System) mainly need 3 things, water/moisture, nutrients, and oxygen (Hydroponics Systems, n.d.). Hence the team decided to use Aeroponics method to grow plants.

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For both hydroponics and aquaponics system, water conservation is 90% less when compared to traditional farming (Hydroponics Systems, n.d.). It does not require farmland with fertile soil, and it can be done on sand, gravel rocky surfaces. Energy conservation is less when compared to conventional farming. Food scarcity can be reduced to a certain extent by increasing the local yields. (Figure 6)
in a HDB or Condominium. This adds value to “Clean & Green Singapore” (CGS) campaign initiated by Singapore Government that provides a platform to connect people from different communities, to develop life-long learning skills and for active aging.

Implementation

During the implementation phase, students not only learned technical skills, but were also introduced to other skill sets such as strategic planning, purchasing, and marketing of their prototypes.

One of the project was to build an automated monitoring system that minimises the need of physical intervention. The team used Raspberry Pi to integrate sensors to monitor different parameters such as temperature, pH value, and water level. UV light and water pump were automatically controlled whenever it exceeded the threshold value, which is pre-set within the system. The web/mobile based system, Figure 7 gave the flexibility for the user to change the pre-set threshold values remotely as needed.

The teams decided to build their own system from scratch. Indonesian students have the skill sets of drilling and soldering while Singapore students are strong in their problem-solving skills. Their sharing and effective use of cross cultural skill sets, Figure 7 provided a source of experience for innovative thinking and collaboration between students from both countries.

![Figure 7: Building an Aquaponics system](image)

Some advantages of the system is electricity saving, real-time monitoring, less physical intervention, reusing and recycling of the waste from fish to plant and vice versa. To summarize, students’ take-away from this project is a better understanding of the Reduce-Reuse-Recycle (3R) system. Referring to Kolb’s theory, students learnt new skills in both technical and non-technical areas which led them to create and experiment within the system. Based on the observations, the students lacked in certain skills in reusing the waste from plant to feed the fish and vice versa.

Another project was to build an indoor Aeroponics system in which air or mist environment was used as a medium instead of soil or an aggregate medium. This method uses less water and energy to grow plants together with less maintenance. The system in Figure 8 will create mist using water and spreads the mist automatically to the roots of the plants for 15-20 minutes. The system uses the smart IoT device, Raspberry Pi to a relay that integrates and controls various parameters such as temperature, humidity, water levels. The Raspberry Pi camera module captures the images at various intervals and a program is used to continuously monitor the growth of plants.

![Figure 8: Aeroponic System](image)

Both projects were focussed on the ultimatum to overcome the food scarcity and food security. It helps to lead a healthier life style by growing pesticide free garden-fresh greens at low cost. In addition, it nurtures the habit of developing passion towards gardening among young citizens and serves as a platform to integrate family members, communities through bonding sessions not only locally but also across countries.

Reflection

Even though Singapore and Indonesia are neighbouring countries, some form of individualism exists for two countries. Students are from diverse ethnic, social, and cultural background. Hence the most important things are to make them feel comfortable, particularly for Indonesian students when they are in a foreign country. Ice-breaking sessions played a vital role in them to open-up and share their personal capabilities and to break down the barriers between them. The team bonding sessions served as a platform to socialize and to understand the cultural similarities and differences between two countries. Field trips established a variety of cultural exchange sharing experiences that helped students to recognize and appreciate the similarities and differences between two countries. For most of the Indonesian students it was a memorable event as this was their first overseas visit in their life. The learning journeys provided a platform for good networking session.
For the implementation of project, the students managed to come up with a prototype, fusing together urban farming and technology. Solutions proposed are relatively cost-effective, low energy consumption, scalable and pesticide free. Yet they had challenges in reusing and recycling the fish waste to plants and vice versa. The challenges faced by the students were cultural differences to communicate between each other, lack of IoT skills and problem-solving skills. Nevertheless, with the help of ethical guidance, they managed to overcome those challenges and had smooth transition to complete the projects.

Feedback gathered

Feedback gathered from the students shows their involvement to understand diverse cultural perspectives that leads to both personal and professional growth. Below are the quotes extracted from students’ feedback.

“Aeroponics and Hydroponics are an eye-opener to how a simple design requires tremendous amount of work if done on a large scale...Apart from learning from the excursions, it also made me felt a sense of pride and relief that I will be a part of the IT industry in the future.” – Student A

“The most memorable thing in Singapore was to go to our Faci, house for Deepavali celebration.” – Student B

"4 oct 17 — then at the 3rd day we start to explore the project problems definition with exploring some farming house in Singapore. At the first farming house I was so excited with the presenter.” – Student C

Conclusion

To conclude, authors found that cross-cultural differences exist among students and it has an impact on communication among students between two different cultures. They believe that the TFI SCALE platform provided a framework to build bridges between student leaders from a polytechnic in Singapore and Indonesian Institutions. The three-week bonding programme helped to overcome the barriers and helped in the understanding of the strengths and weaknesses of individualism, to build a smooth relationship across two countries and to develop their leadership skills through cross-cultural networks. It provided a platform to share the similarities and differences between the students from the two countries. Further, it helped them to address the common issues between two countries and co-create feasible solutions. Along their journey, students learned to apply their critical thinking skills to innovate new ideas to discover the customer needs that can be translated into opportunities. They also gained experience to test those innovative ideas, to overcome the challenges in implementing them and reflecting back to generate a more feasible solution. In this paper, authors used Kolb’s Experiential Learning styles to co-develop solutions to address social and community issues to implement new technologies and techniques in urban farming.

Authors conclude that due to cultural socialization, when students from different culture communicate to work together, they explore different leaning styles to improve their cognitive and behavioural skills.

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References


Abstract

Today’s students are more technology literate. Instant Messaging (IM), as one of the use of learning technologies, has had a significant impact in education and has brought amazing changes to pedagogies. However, many of the public IM tools are primarily used for non-academic discourse, and if they are used in academic contexts, it requires not only well-understanding of student-centred learning and teaching approach but also good instructional design and online facilitation skills.

Two cohorts of students using public and private IM tools from the same module named Highway Engineering (CON4381) of Higher Diploma in Civil Engineering at the Hong Kong Institute of Vocational Education (Tsing Yi) were selected for a case study. A comparative method was used to find out why the cases are different and to discuss such a variation. A descriptive comparison was made to describe and explain the invariances about such application of IM tools. With an approximate class size of 300 students for each cohort, the research in this paper focuses on the teachers’ perceptions of the IM and answers the following questions:

- What are the advantages and disadvantages of both public and private IM tools in educational contexts?
- What are the key factors of consideration when introducing a public IM tool for Technology Enhanced Learning?

The results revealed that significant differences were found across the applications of public and private IM tools in education both positively and negatively. Being exploited as a social rather than an academic medium, this research has a significant implication on how these public tools can be more effectively incorporated into the educational experience and fosters an effective learning environment through three key factors of consideration: usability, innovation and security.

Keywords: Instant messaging, public and private, Telegram, VTC@HK IM, usability, innovation, security.

Introduction

The rapid growth in the number of students who use Instant Messaging (IM), as well as the amount of the time students spend on it, opens opportunities and creates challenges for higher education institutions. IM, in general terms, enables individuals to easily communicate with families and friends in real time and is primarily used for non-academic discourse. However, for educational purposes, using IM in education requires not only well-understanding of student-centred learning and teaching approach but also good instructional design and online facilitation skills. This may not be an easy task for teachers.

In previous researches, a particular focus on the educational impact of public IM tools has rarely been examined. Being exploited as a social rather than an academic medium, it is important to better understand how these public tools can be incorporated into the educational experience.

This paper illustrates the application of IM in a case study on Telegram (a public one) vs. VTC@HK IM (a private one). The advantages and disadvantages of both public and private IM tools are discussed. By comparing with a private IM tool, the purpose of this study is to identify the key factors of consideration when introducing a public IM tool for conducting effective communication and fostering students’ self-paced learning in an online setting.
Literature Reviews

The use of IM is pervasive as 42% of Internet users report using IM and 63% of those users indicate that they use IM several times during any given week (Shiu & Lenhart, 2004). Given its pervasiveness, it is natural that IM has also found its way into educational settings. Farmer (2005) suggests that since many students are already familiar with instant messaging, it can be used as a tool to foster an engaging learning environment. In addition, IM can also foster community between learners. Nicholson (2002) found that students who utilized instant messaging were “more likely to agree with the statement that they felt a sense of community with classmates” than those who did not utilize instant messaging. Within the literature, the benefits of IM in the development of community appear to be greater for student-to-student conversations than student-to-teacher conversations, and more notable in distance education courses.

Academic vs. Social Uses of Instant Messaging

IM, which sends messages in real time, has become one of the most popular applications of the internet to stay people connected. Apart from the most common use for social purposes (Pew Research Center, 2015), various public IM tools such as Telegram, WhatsApp, Line, WeChat, Twitter and Skype have been employed to facilitate student learning and to provide a variety of opportunities in academic contexts (Bakker et al., 2007; Brett, 2008; Lauricella & Kay, 2013; Quan-Haase, 2008). The tremendous potential of this technology to activate deep student engagement and to support collaborative learning has been widely acknowledged by many scholars (Tinto, 2003; Ng'ambi & Brown, 2009; Cifuentes & Lents, 2010; Echeverría et al., 2011; Timmis, 2012; Kim et al., 2013).

Instant Messaging in Educational Environments

Lauricella et al. (2013) praise instant messaging as a useful and viable tool for augmenting student’s communication among peers and faculty in higher education. Litchfield et al. (2007) found that students are positive about using mobile devices in education and hence suggest that mobile learning has a high potential to be utilised in teaching and learning. In higher education, mobile devices have remarkable features which can create more effective learning environments for traditional classes (Kert, 2013). Kim et al. (2013) also praise the development of mobile technologies has enabled educators to send instructional messages in flexible ways. However, instructional decisions have been shown to influence the quality of student-to-student online discussions, with lack of teacher guidance and intervention having a negative effect (Hou, Chang, & Sung, 2007).

Methods

An action research was done to describe the situation. Two cohorts of students who were studying the same module named Highway Engineering (CON4381) of Higher Diploma in Civil Engineering at the Hong Kong Institute of Vocational Education (Tsing Yi) were selected for study. Students of cohort 2016/17 and cohort 2017/18 use Telegram (public IM tool) and VTC@HK IM (private IM tool) respectively in assisting teaching and learning. Brief introduction of both IM tools are provided in the following paragraphs.

Telegram

Telegram is a cloud-based IM service. Users can send messages and exchange photos, videos, stickers, audio, and files of any type, in which it specializes in text chat and file sending. It is completely free to use, has no ads, and no paid perks. Communication is between a user and the user’s Telegram contacts only and all messages are encrypted. For extra security, one can set certain messages to self-destruct after a given time. Sent files can be of any type, and media can be stored on Telegram’s cloud if needed.

VTC@HK IM

This mobile app supplements VTC’s Moodle Learning Management Platform through strengthening communication among students as well as between students and teachers. It allows students and teachers under the same Moodle course to share thoughts and collaborate interactively through the use of instant messaging, without the need of disclosing sensitive personal information such as mobile phone numbers.

Research Questions

Direct focus on the educational impact of public communication tools has not been examined in previous research. This study investigates how the usefulness and differences between public and private instant messaging when these tools are used to communicate between the instructor and students. To date, this comparison has not been examined. The research in this paper focuses on the teachers’ perceptions of the IM and answers the following questions:

- What are the advantages and disadvantages of both public and private IM tools in educational contexts?
- What are the key factors of consideration when introducing a public IM tool for Technology Enhanced Learning?
Results and Discussion

Difference of Public vs. Private IM Tools

Taking Telegram and VTC@HK IM as the examples of public and private IM tools respectively, it was found out that usability, innovation and security were the most three key factors of consideration. However, the key pros and cons of public and private IM tools largely depend on the technical expertise and resources available. The following table has a summary:

<table>
<thead>
<tr>
<th></th>
<th>Public IM Tool</th>
<th>Private IM Tool</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Usability</strong></td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td><strong>Innovation</strong></td>
<td>Unrestricted flexibility / Hard to attract research and development / Fostering innovation through forums and surveys</td>
<td>Restricted flexibility / Easier to attract research and development due to rich resources</td>
</tr>
<tr>
<td><strong>Security</strong></td>
<td>Doubtful</td>
<td>More secure because it is fully tested</td>
</tr>
</tbody>
</table>

Usability

For education, public IM tool is generally not reviewed by usability experts and educators. User guides are not required by law and are therefore often ignored. When manuals are written, they are often not specific for educational purpose and sometime difficult to follow. For private IM tool, usability is a high selling point due to expert usability testing and users’ feedback for a more targeted audience. User manuals are also provided for immediate reference and quick training along with support services.

Innovation

Telegram is an open source project and anyone can study their application programming interface (API), protocol and source code and make an informed decision. Such public IM tools could provide flexibility and freedom to change the software without restriction. However, the software providers often struggle to attract large-scale research and development which in turn limit the future support and growth of the software.

However, it has dedicated online communities that share ideas and strategies through forums and surveys, fostering innovation and allowing the product to adapt with changing needs. On the other hand, private IM tool is available for specific users only. Unlike public IM tool, it could attract research and development due to rich resources in order to regularly offer new products and upgrades.

Security

Security of public IM tool is often a concern because it is not always developed in a controlled environment. There is a lack of continuity and common direction that prevents effective communication. Once more, the public IM tool is not always peer-reviewed or validated for educational purpose.

On the other hand, private IM tool is generally seen as more secure because it is developed in a controlled environment by a concentrated team. The team is the only group that can view or edit the source code and this restriction ensures the security and reliability of the software that is fully tested and offered to all users. To use VTC@HK IM, since the mobile app uses VTC Computer and Network Accounts for secure authentication, no mobile phone number has to be disclosed. Only authorized Moodle users may use the mobile app as it is tightly integrated with the Central Moodle Platform.

Limitations

Like all research, the present research is not without some limitations. First, the research only examined students from the Hong Kong Institute of Vocational Education (Tsing Yi). Students on different campuses might generate different results about IM and its effects on the ways students achieve social and academic integration. Second, the method that was employed to compare both IM tools might skew the results as well. Selective scopes of studies might have greatly influenced the results. The directions of studies and observations of researcher could influence a lot.

Despite these limitations, previous research has not explored the impact of different types of IM tools has on college students for academic purposes. Therefore, this study provided rich information about how IM tools might be used associated with academic and social integration.
Conclusions

Students are more technology literate and Internet savvy than ever. In this connection, IM has been growing rapidly and appears to be a preferred mode of communication in higher education.

This paper presented what a teacher/an educator should think about before the use of IM technology in order to achieve improved students’ learning effectiveness. It was particularly useful for those who would adopt non-academic communication IM tools such as Telegram, WhatsApp, Line, WeChat, Twitter and Skype in educational contexts. There were three key aspects of considerations, namely usability, innovation and security, be addressed for the two public (Telegram) and private (VTC@HK IM) IM tools.

Both IM tools have their own advantages and disadvantages in educational contexts. The studies were constructive and the impacts of those technologies were analysed. For example, the public IM tool has low usability in term of educational applications, however, it offers unrestricted flexibility that could foster innovation through forums and surveys. In this paper, using IM mobile applications “Telegram” and “VTC@HK IM” could no doubt enhance students and teachers’ effective communication. Technology Enhanced Learning is achieved for classes using this e-pedagogies in communication to increase students’ engagement and motivation.

In current technology-enhanced learning environments, benefits can be achieved through facilitating e-Learning environment, motivating students with educational technology tools and identifying the characteristics and essential elements for planning blended and flexible learning.

References


OVERVIEW OF START-UP ACTIVITIES WITHIN THE ONLINE-BASED EDUCATIONAL FRAMEWORK OF KOSEN SPACE ACADEMIA

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Abstract

This paper describes the activities of the KOSEN Space Collaboration, organized by teachers from the National College of Technology (KOSEN) who specialize in space science and engineering. KOSEN does not have a dedicated department for space science and engineering, so there are limited opportunities for interested students to develop skills and expertise in these fields, even though space agencies and manufacturers of space equipment in Japan are greatly inclined hiring KOSEN students. Grassroots KOSEN Space Collaboration members have gathered together to organize the KOSEN Space Camp every summer since 2015. At this camp, KOSEN students attend lectures delivered by first-line researchers and compete in creating a model rocket and a pico-satellite CanSat model. KOSEN teachers use the opportunity to exchange information about study materials on space science and engineering. Since 2017, we have employed a new educational framework under a three-year grant-in-aid from the Ministry of Education, Culture, Sports, Science and Technology (MEXT)—'KOSEN Space Academia,' started in 2018—using online-based conference systems. The Academia’s students currently attend lectures and practical trainings on space science and technology. KOSEN Space Collaboration has developed new teaching materials, such as a CanSat kit for beginners, a CubeSat model with functions comparable to those of real satellites, and a simple receiver with a software-defined radio (SDR) for satellite transmission. Using these equipments, our students can experience a complete series of events from the development of a satellite to a rocket launch and to subsequent data reception from the satellite. In this paper, we describe the initial activities of the KOSEN Space Academia and discuss our plans for the future.

Keywords: space technology, space science, CanSat, model rocket, CubeSat model, SDR

Introduction

Our modern life is supported by many satellites, including meteorological, communication, and GPS satellites. Since small satellite development is being conducted by universities and companies, there are challenging opportunities for engineering students. In universities, students can be involved in developing small satellites, especially in departments of space science and engineering. In fact, various educational approaches have been carried out (e.g. Nakasuka et al., 2010; Miyazaki & Yamazaki, 2013). For educational purposes, some university students even tried to create a CubeSat model (Yamazaki, 2016). In Japan, there are several contests for CanSats (satellites that fit in a soda can) and/or model rockets open to university and high school students.

In support of this growing field, the KOSEN Space Collaboration was organized by teachers specializing in space science and engineering from the National College of Technology (KOSEN) to help students develop such skills and expertise. KOSEN students, including the same age as both university and high school students, gain training in technical fields such as space development. Some KOSEN graduates are active in domestic space agencies and space related manufacturers; several space agencies and manufacturers of space equipment in Japan are greatly inclined hiring KOSEN students. However, because
KOSEN does not have a dedicated department for space science and engineering, there are limited opportunities for students aspiring for relevant institutions and companies to develop their skills and expertise in these fields. Although the space engineering is a complex system, general engineering skills are often included such as mechanical engineering, electrical and electronic engineering, information technology, and civil engineering etc.

The KOSEN Space Collaboration, whose members have gathered together at the grassroots level, have organized the “KOSEN Space Camp” every summer since 2015 (Wakabayashi et al., 2018; Kitamura et al., 2018). In these camps, KOSEN students attend a special lecture delivered by first-line researchers and create a model rocket and CanSat for beginners. The main event is the competitions for group CanSat production. In the competition, students must design an original mission and develop a unique CanSat in just three days and work with other KOSEN students (Tsubouchi et al., 2018). Space Camp combines mission design in the space development field with exposure to manufacturing that KOSEN students are generally good at. Space Camp has provided valuable hands-on training and teamwork opportunities for KOSEN students.

At beginning in 2017, we instituted a new educational framework under a three-year grant-in-aid from the Ministry of Education, Culture, Sports, Science and Technology (MEXT), as a way of reaching out to and educating interested students and qualified teachers and lecturers across Japan. We call this new framework KOSEN Space Academia. Created in 2018 using an online conference system, KOSEN Space Academia enables students to attend lectures and practical trainings based on space science and technology. In this paper, we describe the initial activities of the KOSEN Space Academia and discuss our plans for the future.

Academia’s lecturers are teachers from each of the Space Collaboration member KOSENs. Three KOSENs (Kochi, Gifu, and Aakashi) form three node schools in the network of KOSEN Space Academia and oversee the development and preparation of teaching materials. All KOSEN space collaboration members cooperate with each other to develop and prepare various educational materials. We distribute physical educational materials (e.g. printed materials, CanSat kits, etc.) from the node schools to participating KOSENs nearby, keeping delivery costs low. Participating students choose a KOSEN teacher as their contact person for receiving deliveries, preparing online conferences, and so on.

Start-up Activities of KOSEN Space Academia

In academic year 2017, we held a kick-off meeting at the Tokuyama KOSEN in January, followed by follow-up lectures at an online conference. In academic year 2018, we have recruited new Space Academia students and, as of April, have been holding lectures, practical trainings, online conferences, etc., once a month. Figure 3 shows leaflets from the January 2018 kick-off meeting for the first half of 2018. The kick-off
meeting featured a special lecture delivered by Dr Tomohiro Ishikawa of the Tokyo Metropolitan College of Industrial Technology, who spoke on ‘Satellite Development by the College of Technology’. A ‘Workshop on satellite communication by a simple receiver was instructed by one of our members, involving production practice. Eleven faculty members and 15 students participated. For the 2018 KOSEN Space Academy, there are 66 students (from 13 KOSENs, with 15 teachers) currently taking classes. The main educational topics and content for the first half of 2018 are model rocket production, CanSat production, and lectures on model rockets and CanSat.

Figure 3. Leaflets for the KOSEN Space Academy 2017 kick-off meeting (left) and 2018 online lecture series (right), written in Japanese but including information of theme, titles, schedules, programs and so on.

Figure 4. Sample educational materials: simple receiver and antenna (left and upper left), model rockets (upper right), CanSat (lower left), and CubeSat model (lower right).

Figure 4 shows some of the teaching materials actually produced (or to be produced) by the KOSEN Space Academy’s start-up activities: a simple receiver and an antenna for satellite radio waves, a model rocket for beginners (ready-made), a CanSat for beginners, and a CubeSat model. These teaching materials simulate the real rockets, satellites, and ground receiving stations involved in actual satellite development and deployment. Educational tools can be easily accessed by students for use in experiments. Important elements that explain the functions of actual satellites are included. These are useful teaching materials for space and human resources education. Most of the tools, such as a simple receiver, a CanSat kit, and a CubeSat model, were developed by the KOSEN Space Collaboration group.

A simple receiver for real satellite radio waves is a device that combines a small computer board with an antenna and uses a software-defined radio (SDR) (Tokumitsu et al., 2017). At the workshop, we demonstrated assembling simple receivers, executing instructions with them, and receiving test waves. In addition, all participants brought their receivers to their KOSEN and conducted actual satellite radio receiving experiments. For the results, at an online conference, the students reported to each other. Figure 5 shows students involved in production practice of the simple receiver and antenna.

Figure 5. Production practice with the simple receiver and antenna at the laboratory in Tokuyama KOSEN.

Figure 6. The online-based model rocket production course in progress.

At the KOSEN Space Academy that began in academic year 2018, 66 students submitted applications for the year. The first lecture was a model rocket course that included 50 minutes of theoretical lecture and one hour of kit production. Although it involved off-site work demonstrated via an online conference system, there were no big problems, and many students completed the model rocket. By launching their model
rockets at the camp to be held in the summer (Kajimura et al., 2017), participants will be qualified for a fourth-grade license from the Japanese model rocket association. Figure 6 shows the online-based model rocket production course in progress. Communicating via Skype, students worked in each workspace while receiving explanations by slide and instructions from the lecturer.

The second and third courses of KOSEN Space Academia covered CanSat production for beginners. This provides a hands-on introduction to real satellite development, mainly for college students (Colin, 2017). For our course, we used a CanSat kit with a small can size of 160 ml (Issiki et al., 2017). Producing a CanSat involves a lot of manual work such as circuit connection by bread board, soldering, cutting and drilling empty cans, and parachute making using plastic bags. Figure 7 shows a CanSat kit for beginners and it was prepared and distributed by three academic base KOSENs.

![Figure 7. CanSat kit for beginners.](image)

Figure 7. CanSat kit for beginners.

![Figure 8. The online-based CanSat course in progress.](image)

Figure 8. The online-based CanSat course in progress.

Figure 8 shows the CanSat production course in progress via the online conference, where one CanSat kit was assembled by one or two students. Since this was the first time for us to conduct practical training using an online conference system, we had the same lesson for two days. As the results, the group of participants was divided almost in two. This helped us learn a lot about remote practical trainings—for example, that the number of connection sites should ideally be fewer than ten. The produced CanSats will be launched by model rocket during the summer Space Camp.

**Results of Questionnaire on KOSEN Space Academia’s Activities**

Regarding the activities of KOSEN Space Academia, participating students and faculty members were asked to respond to a questionnaire. Table 1 shows some of the results of the questionnaire for the model rocket course. Out of 65 participants, 49 students completed the questionnaire. Most of the students showed great interest in the course itself and were mostly satisfied with the contents. However, there were some problems with the smoothness of the Skype communication since there were too many connection points. Based on this result, we changed to using Skype for Business for the next lecture instead of plain Skype. Further analysis of the questionnaire results, including the CanSat course, will be done after Academia’s complete lecture series on the practical training via an online conference.

**Table 1. Results of Questionnaire Covering the Model Rocket Course**

<table>
<thead>
<tr>
<th></th>
<th>Good</th>
<th>Normal</th>
<th>Bad</th>
</tr>
</thead>
<tbody>
<tr>
<td>Was the content</td>
<td>57%</td>
<td>31%</td>
<td>10%</td>
</tr>
<tr>
<td>interesting?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Was the Skype</td>
<td>20%</td>
<td>31%</td>
<td>31%</td>
</tr>
<tr>
<td>picture easy to see?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Was the Skyped</td>
<td>24%</td>
<td>31%</td>
<td>20%</td>
</tr>
<tr>
<td>voice easy to hear?</td>
<td></td>
<td></td>
<td>24%</td>
</tr>
</tbody>
</table>

**Future Plans and CubeSat Model Competition**

Although the activities of the KOSEN Space Academia have just begun, Table 2 lists the activities up to the present and the schedule until the first half of academic 2018. The courses have held at a pace of one a month. The series of activities is connected to the activities at the Space Camp held during summer vacation. The schedule of the second half of the year will be adjusted in the future, but it is intended to incorporate lectures on real rockets and satellites and to incorporate applied practical training using the teaching materials produced so far. For the next academic year, we are considering how to continue courses for beginners and for participating students who wish to continue to attend.

The KOSEN Space Camp, which has been held every summer since 2015, lasts three nights and four days. KOSEN students who are interested in space can experience a special lecture by a first-line researcher, a build and launch a model rocket, produce a CanSat, and the group competition for CanSat experiments. It is confirmed that they gained valuable experience that is not generally provided through daily classroom activities. In this academic year, we were able to teach beginners to produce model rockets and CanSats in
KOSEN Space Academia. Thus, we decided to challenge the students with the creation of a somewhat advanced CubeSat model at the camp. In addition, we are trying new ventures such as holding a CanSat contest for high school students in Shikoku in parallel and implementing an Ideathon related to satellite development. Table 3 shows the schedule and program of Space Camp 2018.

Table 2. Schedule of KOSEN Space Academia for 2017 and 2018

<table>
<thead>
<tr>
<th>Date</th>
<th>Type</th>
<th>#</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/7–8</td>
<td>Meeting</td>
<td>15</td>
<td>Special lecture Simple receiver production</td>
</tr>
<tr>
<td></td>
<td>(Shunan) + Skype</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2/28</td>
<td>Download doc.</td>
<td>-</td>
<td>Simple receiver follow-up</td>
</tr>
<tr>
<td>3/28</td>
<td>Skype</td>
<td>5</td>
<td>Telemetry receiving experiment</td>
</tr>
<tr>
<td>5/24*</td>
<td>Skype</td>
<td>65</td>
<td>Model rocket</td>
</tr>
<tr>
<td>6/19 or 20</td>
<td>CubeSatB</td>
<td>16+</td>
<td>CanSat production 1</td>
</tr>
<tr>
<td>(2 hr)</td>
<td></td>
<td>6+8</td>
<td></td>
</tr>
<tr>
<td>6/27</td>
<td>CubeSatB</td>
<td>4</td>
<td>CanSat production</td>
</tr>
<tr>
<td>(2 hr)</td>
<td></td>
<td>2</td>
<td>[free connect.]</td>
</tr>
<tr>
<td>7/18 or 19</td>
<td>CubeSatB</td>
<td>27+26</td>
<td>CanSat production 2</td>
</tr>
<tr>
<td>(Video)*</td>
<td>(2 hr)</td>
<td>(6+6)</td>
<td></td>
</tr>
<tr>
<td>8/16–22*</td>
<td>CubeSatB</td>
<td>-</td>
<td>Rocket and CanSat application</td>
</tr>
<tr>
<td>(2 hr)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8/30–9/2*</td>
<td>Camp</td>
<td>-</td>
<td>Special lecture CubeSat production Ideathon</td>
</tr>
<tr>
<td>(Nihama)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
*plan (): number of teachers

Table 3. Program Plan of KOSEN Space Camp 2018

<table>
<thead>
<tr>
<th>Date</th>
<th>AM1</th>
<th>AM2</th>
<th>PM1</th>
<th>PM2</th>
<th>night</th>
</tr>
</thead>
<tbody>
<tr>
<td>8/30 Thu.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Special lecture</td>
</tr>
<tr>
<td>8/31 Fri.</td>
<td>CubeSatM group production</td>
<td>Rocket launch</td>
<td>CubeSatM competition -1</td>
<td>Welcome party</td>
<td></td>
</tr>
<tr>
<td>9/1 Sat.</td>
<td>CanSat contest for high school students</td>
<td>Ideathon</td>
<td>Radio Receiving</td>
<td>CubeSatM competition -2, 3</td>
<td>Exchange meeting</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Radio Receiving</td>
<td>Ideathon</td>
</tr>
<tr>
<td></td>
<td>Presentation</td>
<td>Prize-awarding</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4. CubeSat Model Competitions for Space Camp

<table>
<thead>
<tr>
<th>Functions of CubeSat Model</th>
<th>Contents of Competitions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power supply system</td>
<td>• To monitor solar panel and battery</td>
</tr>
<tr>
<td></td>
<td>• To compete the status of long-time data acquisition</td>
</tr>
<tr>
<td>Attitude system</td>
<td>• To determine the attitude with several sensors</td>
</tr>
<tr>
<td></td>
<td>• To complete accurate positioning in the field of view (FOV) of the camera</td>
</tr>
<tr>
<td>Communication system</td>
<td>• To complete successful communication conditions during a 10-min flight in the sky (using captive balloon)</td>
</tr>
</tbody>
</table>

The CubeSat model is a kit for building a box-shaped nanosatellite called CubeSat and is designed to operate on the ground (Yamazaki, 2016; Tanaka and Kitamura, 2017). It is made mainly for educational purposes and has functions similar to those of CubeSats released into space. In the camp, we plan to produce this CubeSat model focusing on the assembly, and we plan to have groups take part in experimental competitions. This will be the first time we will hold the CubeSat model competition, which will give students a structured setting to try the challenges for each of the main functions of CubeSat model, such as the power, attitude, and communication systems. Then we will comprehensively evaluate the data and present an analysis of the results, highlighting the uniqueness of their ideas and problem-solving achievements. Table 4 shows specific plans for each function. We hope that our educational materials and the design of the competitions will fuel the students’ aspirations.

Summary

To nurture space personnel capable of contributing to real satellite development, we have started designing, practicing, and refining an educational system: KOSEN Space Academia. In KOSEN Space Academia, we use online video conferencing to reach and to connect interested students and teachers spread among multiple different KOSENs. This paper described the main startup activities: working with a simple receiver with a software-defined radio, making a model rocket, and building a CanSat for beginners. In addition, we presented our plans for the group production of and competition with CubeSat models at the KOSEN Space Camp in August in 2018. KOSEN Space Academia’s educational focus is currently on manufacturing and hands-on training for KOSEN students. This is implemented through long-distance lectures, practical training sessions, and discussions via online video conferencing. We confirmed that our online-based system functioned well, with only minor difficulties relating to bandwidth with Skype. Regarding the development and distribution of teaching materials, it is confirmed that three KOSENs distribution bases for delivering materials and coordinating with neighbouring participating colleges works effectively. In the future, we hope to enhance our expertise in delivering practical lectures and hands-on training using an online conferencing system and to build an increasingly fulfilling curriculum.

Acknowledgements

We acknowledge all the members of the KOSEN Space Collaboration group and all the participants in KOSEN Space Academia 2018. We are very grateful to the students of National Institute of Technology at Yonago College, Kochi College, Gifu College, and Akashi College for the help we received in preparing the simple receiver and CanSat kits. The KOSEN Space Technology Education Project was supported by the Human Resource Development program of MEXT, Japan, in 2017. This work was supported by JSPS KAKENHI Grant Number JP17K01169.

References


QUALITY DIMENSIONS AND STRATEGIES OF MOBILE LEARNING

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Abstract

The proliferation of mobile devices among especially the younger generations has led to a change in expectations and appetite when it comes to learning. Learners now prefer to learn "on-the-go" and to have the learning contents literally at their fingertips. It is hence imperative that educational institutions evolve accordingly by making more of their contents "mobile friendly". However, robust frameworks and design strategies for mobile learning are still in the nascent stages of education research. This research builds on existing literature in the field of mobile learning pedagogy to propose novel mobile learning quality dimensions and strategies, which instructors can use to design their own courses.

The research is conducted on 120 identified learners from 2 faculties, School of IT and School of Health Sciences who were undertaking their respective core modules. The participating instructors designed mobile learning packages in accordance with the proposed mobile learning quality dimensions and strategies and disseminated the packages to the learners. The authors collected feedback from learners via survey questionnaires on a four-point Likert scale to measure the level of learners' satisfaction with the mobile learning packages. The authors also examined the module learning outcomes through classroom observations coupled with discussion with the instructors to gauge the level of instructors' satisfaction as well as the level of attainment learners achieved in the required competencies.

Both qualitative data and sentiments are collected from survey and classroom observations have been encouraging. The qualitative data collected measured the effectiveness of the proposed design strategies against various quality dimensions for mobile learning from existing literature. Collection of sentiments has shown that the positive acceptance of the proposed strategy by both the learners and instructors.

This research has established a fundamental set of quality dimensions and design strategies dedicated for developing mobile learning content. The preliminary results demonstrate that the design strategies are effective and mobile learning appeals to the modern learners' appetite for convenience and flexibility to learn "anywhere, anytime".

The quality dimensions and strategies recommended are to be adopted by the instructors when designing mobile learning contents for their module.

Keywords: Mobile Learning, Elearning, Mlearning, Quality Dimensions, Design Strategies

Introduction

Mobile electronic devices have come a long way, from being a niche technology to being an almost ubiquitous tool that touches a myriad of fields in the world. In the realm of education, schools and educators are incorporating mobile learning into their curriculum steadily to tap on the affordances of mobile devices as well as the availability of these devices in the hands of learners.

In the past two decades, research into mobile learning has picked up pace, with numerous frameworks for mobile learning being suggested by different groups of researchers. At the same time, multiple reports have shown that there is a gap between the translation and adoption of research results and theories into actual practice, be it in education or other fields of studies.

This paper attempts to bridge this gap by presenting “middle layers” that can be introduced between the theoretical frameworks and the concrete steps that educators can adopt to implement the rich body of research on mobile learning to their own curriculum design. These “middle layers” are split into 1) quality dimensions that are framework-facing, and 2) mobile learning strategies that are practice-oriented. Mobile lessons based on these “middle layers” were created and data were gathered to assess their effectiveness.

Background

The number of mobile phone users have steadily climbed throughout the years and is expected to exceed 5 billion in 2019 (Meena & Kumar, 2017). Though originally created for adults for business use, young
people has adopted mobile technology so readily that the mobile phone has already become an essential component in their lives, even more so than adults (Campbell, 2005), so much so that Ling (2000) even stated that the mobile phone is “at cross purpose with the mission of the school”. Forward-looking researchers and institutions have accepted the paradigm shift, and many have embarked on incorporating mobile learning into their curriculum (Kljunić & Vukovac, 2015; Oberer & Erkollar, 2013; Taleb & Sohrabi, 2012; Wang, Shen, Novak & Pan, 2009).

It is Sharples et al. (2009), who have one of the more encompassing definitions of mobile learning, unpacked mobile learning into 1) mobility in physical space, 2) mobility of technology, 3) mobility in conceptual space, 4) mobility in social space, and lastly 5) learning dispersed over time. Regardless of the definition, it is commonly recognized that mobile learning is a subset of electronic learning (elearning) with its own characteristics and constraints (Parsons & Ryu, 2006).

In the past two decades, research into mobile learning has picked up pace, with numerous frameworks for mobile learning being suggested by different groups of researchers. Koole’s (2009) FRAME (Framework for the Rational Analysis of Mobile Education) model “describes mobile learning as a process resulting from the convergence of mobile technologies, human learning capacities, and social interaction.” It is a comprehensive framework that takes into account not only the technical affordances of mobile devices, but also the social and personal aspects of learning. In this paper, we propose two middle layers between Koole’s FRAME model and actual practice to simplify the theory for instructors to implement in their mobile lesson design. Two middle layers are proposed instead of one so that there is less information dropped at each layer.

Proposed Quality Dimensions

Using Koole’s FRAME model as the framework for choice, we crafted quality dimensions as rhetorical guiding questions that could be mapped from the overlaps between the circles in the FRAME model. As shown in Figure 1, we are using Koole’s terminology where the three intersections are abbreviated by the terms DL (Device-Learner intersection, which points to device usability), LS (Learner-Social intersection, which points to interaction technology), and DS (Device-Social intersection, which points to social technology). These questions were based on multiple research on mobile learning and aim to condense the knowledge and wisdom of these research yet not be too shallow and inflexible.

These nine questions comprise the quality dimensions that this paper proposes to aid instructors in designing mobile lessons, by providing them rhetorical questions to anchor their design in the theoretical framework. However, taking human behavioural science into consideration, we went one step further to create a mnemonic that gives instructors a “chunked” checklist to use when designing mobile lessons. We term the breakdown of this mnemonic “mobile learning design strategies”.

Proposed Design Strategies

The design strategies proposed (see Figure 2) are extracted from both Koole’s FRAME model as well as the quality dimensions discussed above. They are grouped together via the mnemonic MOHICANS to facilitate instructors’ retention and encourage usage. The first three design strategies are general design considerations that stem from the FRAME model directly, while the next five strategies are drawn directly from the quality dimensions.

Quality Dimensions of Mobile Learning

1. Are the learning outcomes clear and concise?
2. Are the contents in “short nuggets”?
3. Are the contents easily navigable?
4. Are the contents readable on a mobile device?
5. Can contents be downloaded to the mobile device and accessed easily?
6. Is the progress of the learner tracked?
7. Are there social interactions for learning between learners and between learners and instructor?
8. Are there formative/self-check and summative assessments?
9. Are there timely and constructive feedback to support learners’ learning?

![Figure 1: Mapping of Koole’s FRAME to Quality Dimensions](image-url)
i. **M** is for “Should it be Mobile?"

The very first general design consideration strategy for instructors when contemplating to create a mobile lesson will be to consider the most pertinent questions: Is it based on a timely and relevant topic that learners would like to have a quick refresher on while on-the-go? Would this lesson be better presented if delivered in a device with a larger form factor or in a physical class?

ii. **O** is for “Off-the-shelf”

The next general design consideration is for instructors to consider off-the-shelf solutions before creating materials from scratch. For example, it would be more useful to embed a video containing animation that could present the materials in a more visually appealing manner than for the instructor to put the contents in textual form.

iii. **H** is for “Honey on the fingertips”

The last general design consideration is for instructors to remind themselves to design their mobile lessons to be interactive so as to keep the attention of learners. Instructors would want to design their mobile lesson so that the lesson seems to be like “honey” which learners would like to “taste” from i.e. make it enticing to learners.

iv. **I** is for “An Icebox is NOT a refrigerator”

This is the first design strategy drawn from the quality dimensions, namely dimensions 3 and 4 (readability and navigability). Although it is true that mobile learning is a subset of elearning, it has such distinct features that simply claiming that one has an elearning lesson means that it can be counted as a mobile learning lesson is a very shallow claim. We hope instructors can use this visual metaphor for an icebox versus a refrigerator to remind themselves to not confuse desktop elearning with mobile learning.

v. **C** is for “Chunk it!”

To facilitate retention for learners of a mobile lesson, research on psychology suggests that chunking large amount of information into small parts helps people to remember things better. For this reason, mobile lesson designers are reminded to chunk both their learning outcomes and contents into small “nuggets” of information to aid learning, vis-à-vis quality dimensions 1 and 2 respectively.

vi. **A** is for “Assets on wheels”

Unless a school or institution started off by creating mobile lessons, educators most probably have their materials in the form of slides or text documents. Transiting to mobile lessons necessitates instructors to put these educational “assets” on “wheels” i.e. unhinged them from the original presentation format (slides or documents) and plug them into the mobile lesson. This is akin to the separation of the presentation from the data in the Model-View-Controller (MVC) architecture in the realm of computer science (Davis, 2008; Heidke, Morrison & Morrison, 2008).

vii. **N** is for “Creating a Learning Nexus”

With regards to quality dimensions 6 and 7, which suggest respectively that the learner’s progress be tracked and social interaction for learning be introduced, we recommend that the mobile lesson be integrated into a Learning Management System (LMS) to tap on the

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**Quality Dimensions of Mobile Learning**

1. Are the learning outcomes clear and concise? .......... C
2. Are the contents in “short nuggets”? ................... C
3. Are the contents navigable? .............................. I
4. Are the contents readable on a mobile device? ......... I
5. Can contents be downloaded to the mobile device and accessed easily? ........................................... A
6. Is the progress of the learner tracked? .................. N
7. Are there social interaction for learning between learners and between learners and instructor? .......... N
8. Are there formative/self-check assessments? ........... S
9. Are there timely and constructive feedback to support learners’ learning? ........................................ S

**Strategies for Designing Mobile Learning**

<table>
<thead>
<tr>
<th>Letter</th>
<th>Strategy</th>
</tr>
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<tbody>
<tr>
<td>M</td>
<td>Should it be Mobile?</td>
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<tr>
<td>O</td>
<td>Off-the-shelf</td>
</tr>
<tr>
<td>H</td>
<td>Honey on the fingertips</td>
</tr>
<tr>
<td>I</td>
<td>An Icebox is NOT a refrigerator</td>
</tr>
<tr>
<td>C</td>
<td>Chunk it!</td>
</tr>
<tr>
<td>A</td>
<td>Assets on wheels</td>
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<tr>
<td>N</td>
<td>Creating a Learning Nexus</td>
</tr>
<tr>
<td>S</td>
<td>Self-Assessment</td>
</tr>
</tbody>
</table>

Figure 2: Mapping of Quality Dimensions to Design Strategies
LMS’s in-built login system, discussion forum etc. This will lessen the burden of the instructors to dabble with networking aspects, while at the same time adhere to the MVC framework.

viii. S is for “Self-Assessment”

Lastly, quality dimensions 8 (assessment) and 9 (timely feedback) are mapped unto the strategy of self-assessment. Mobile lessons should have both in-content mid-lesson quizzes for milestone checks, as well as summative assessments to gauge the overall learning outcomes of the learners. If these assessments could integrate feedback into the answers that learners gave, it would constitute the timely feedback that they need to close the loop on their learning.

Methods

Participants in the present study consisted of 120 identified learners from 2 faculties namely, School of Information Technology and School of Health Sciences. The participating instructors designed their mobile learning contents in accordance to the mobile learning quality dimensions and strategies that was highlighted in this paper. This study aims to find out how quality dimensions and strategies can enhance the quality of learners’ learning. Each learner was surveyed to answer the following questions:

1. The learning outcomes are clear and concise.
2. The content is bite-sized for learning on-the-go.
3. The content is easily navigable.
4. The content is readable on a smart device.
5. The content helped me in fulfilling the assessment required for this topic.
6. There are timely and constructive feedback to support learning.
7. The mobile learning contents have been helpful to me in my learning.
8. The mobile learning contents are self-paced, self-directed and relevant.
9. Overall, I find that mobile learning is good way of learning for me.

Besides the survey results from the learners, the authors examined the module learning outcomes through classroom observations coupled with discussion with the instructors to gauge the level of instructors’ satisfaction as well as the level of attainment learners achieved in the required competencies.

Results and Discussion

In this section, we will discuss the results that was derived from the methods that were explained above. The results from the survey shows that the learners felt that mobile learning contents has helped them in their learning. Results has also shown that 90% of the learners felt that the mobile learning is good way of learning for them.

The following are the key results of the responses collected from the survey.

![Figure 3: The mobile learning contents have been helpful to me in my learning.](image1)

![Figure 4: The mobile learning contents are self-paced, self-directed and relevant.](image2)

![Figure 5: Overall, I find that mobile learning is good way of learning for me.](image3)
Table 1: Summary of responses to Q1-Q6

<table>
<thead>
<tr>
<th>Question</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>The learning outcomes are clear and concise.</td>
<td>Strongly Agree (58.3%)</td>
</tr>
<tr>
<td></td>
<td>Agree (41.7%)</td>
</tr>
<tr>
<td></td>
<td>Neutral (0%)</td>
</tr>
<tr>
<td></td>
<td>Disagree (0%)</td>
</tr>
<tr>
<td></td>
<td>Strongly disagree (0%)</td>
</tr>
<tr>
<td>The content is bite-sized for learning on-the-go.</td>
<td>Strongly Agree (58.3%)</td>
</tr>
<tr>
<td></td>
<td>Agree (41.7%)</td>
</tr>
<tr>
<td></td>
<td>Neutral (0%)</td>
</tr>
<tr>
<td></td>
<td>Disagree (0%)</td>
</tr>
<tr>
<td></td>
<td>Strongly disagree (0%)</td>
</tr>
<tr>
<td>The content is easily navigable.</td>
<td>Strongly Agree (52.1%)</td>
</tr>
<tr>
<td></td>
<td>Agree (39.6%)</td>
</tr>
<tr>
<td></td>
<td>Neutral (8.3%)</td>
</tr>
<tr>
<td></td>
<td>Disagree (0%)</td>
</tr>
<tr>
<td></td>
<td>Strongly disagree (0%)</td>
</tr>
<tr>
<td>The content is readable on a smart device.</td>
<td>Strongly Agree (62.5%)</td>
</tr>
<tr>
<td></td>
<td>Agree (31.3%)</td>
</tr>
<tr>
<td></td>
<td>Neutral (6.3%)</td>
</tr>
<tr>
<td></td>
<td>Disagree (0%)</td>
</tr>
<tr>
<td></td>
<td>Strongly disagree (0%)</td>
</tr>
<tr>
<td>The content helped me in fulfilling the assessment required for this topic.</td>
<td>Strongly Agree (54.2%)</td>
</tr>
<tr>
<td></td>
<td>Agree (39.6%)</td>
</tr>
<tr>
<td></td>
<td>Neutral (6.3%)</td>
</tr>
<tr>
<td></td>
<td>Disagree (0%)</td>
</tr>
<tr>
<td></td>
<td>Strongly disagree (0%)</td>
</tr>
<tr>
<td>There are timely and constructive feedback to support learning.</td>
<td>Strongly Agree (58.3%)</td>
</tr>
<tr>
<td></td>
<td>Agree (31.3%)</td>
</tr>
<tr>
<td></td>
<td>Neutral (10.4%)</td>
</tr>
<tr>
<td></td>
<td>Disagree (0%)</td>
</tr>
<tr>
<td></td>
<td>Strongly disagree (0%)</td>
</tr>
</tbody>
</table>

Both qualitative data and sentiments collected from survey and classroom observations have been encouraging. Sediments from the feedback gathered has indicated that the positive acceptance of the proposed strategy by both the learners and instructors.

Analysis of the collected data revealed that Mobile Learning was effective than the use of traditional teaching pedagogy to achieve the learning outcomes of the topics that the contents are developed in mobile learning packages. Results of the present study have also proved that by using these quality dimensions and design strategies dedicated for developing mobile learning content, there is an increase of interest in learners' learning and has enriched the learners' experience. The instructors have also feedback that the quality dimensions and mnemonic MOHICANS have provided them practical design strategies that helped them to design learning contents suitable for mobile learning. From the score that the learners have achieved in the summative assessment, it can be determined that the learners have achieved the learning outcomes desired of the mobile learning contents. Most of the learners are able to score above 80% after going through the mobile learning contents.

Conclusions and Recommendations

With the proliferation of mobile devices and millennials today have shorter attention span, it is evident that traditional learning content no longer works. They value timely information and rapport with their instructors ("How to engage millennials: 5 teaching strategies for millennials that will work!," 2017). This study aims to address the learning needs of this new generation by bridging the gap between research theory and actual practice with a set of practical quality dimensions and design strategies.

The learner's experience on a mobile device is also very different from any other traditional eLearning platforms (e.g. desktop). This calls for a specialized design strategy for mobile learning. This research has proposed a 2-middle-layer-approach built upon Koole’s FRAME model with quality dimensions (1st layer) and strategies (2nd layer) that lead to a sound mobile lesson design. The results collected from the survey demonstrated the effectiveness of the recommended strategies on mobile learning.

The present study is administered to analyze the advantages of using mobile learning design and strategies that was recommended in this paper. The outcome is measured from the learner and instructor perspective. Quantitative feedback are collected through survey conducted with the 120 learners. 6 instructors are requested to develop mobile learning content based on the quality dimensions recommended for the modules that they teach respectively. 120 learners from 2 faculty contributed to the survey results. Qualitative feedback are collected from the instructors through classroom observations and interviews. Overall, the survey has shown more than 85% of the respondents responded with ‘Strong Agree’ or ‘Agree’ for each question. Therefore, the summarized findings of this study reveal that our proposed approach is effective and practical for learners learning on-the-go, anytime and anywhere.

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References


TEACHING ARTIFICIAL INTELLIGENCE IN VOCATIONAL AND PROFESSIONAL EDUCATION AND TRAINING

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Abstract

Artificial Intelligence (AI) has always been an advanced topic in the field of Computer Sciences and only included in the senior year study of undergraduate degree programmes. It requires the students to have strong logical and mathematical background. The study involves a lot of logical proofs and algorithmic concepts. However, with the popularity of AI in the recent years, AI is no longer a research area but already included in many daily-life’s applications. Therefore, it is necessary for the learners who are studying Vocational and Professional Education and Training (VPET) in the field of Information Technology (IT) to have exposure on this state-of-the-art technology. With the maturity and availability of public Application Programming Interfaces (APIs) from the world-class IT enterprises for building AI applications and easy-to-use frameworks for developing AI algorithms, it becomes a possible task to include AI in the VPET curriculum. In this study, we discuss on the selection of topics, review the existing tools and APIs for building AI applications and specify the essential background of the IT learners. Also, a few case studies will be discussed on the use of AI technologies in the final year projects of IT learners from VPET.

Keywords: Artificial Intelligence (AI), Information Technology (IT), Vocational and Professional Education and Training (VPET)

Introduction

It is no doubt that Artificial Intelligence (AI) is one of the hottest topics around the world. 2017 is claimed as “The Year of AI” (Venkatachalam, 2017). The acceleration of innovation in AI has made it becomes the main focus in the society, the government and the media. Everybody is talking about AI and it is used intensively in different industries already such as the mobile world, online customer support, smart home and city, and automobile and retail industries (MindMajix, 2018). Three-quarters of executives believe AI will enable their companies to move into new businesses. Nearly 85% of them believe AI will allow their companies to obtain or sustain a competitive advantage (Ransbotham, et al., 2018).

AI is growing in adoption especially in 2018. A recent report from IDC shows that Japan will have 74% expected projected growth from 2016-2021 (Manabe, 2018). The US is expected to have 49% compound annual growth, and Western Europe will be around 44% growth. The same report also predicted that around $57.6 billion will be spent in different industries on AI in the coming five years, with this spending set to increase employee productivity, deliver new business insights, and more workflow automation. All these lead to the increasing of AI adoption (Seiz, 2017).

In the education sector, Carnegie Mellon University, one of the AI education leaders, has launched the first undergraduate degree programme in AI, i.e. B.S. in AI, for the 2018/19 academic year, due to the forecast of manpower shortage of specialists in the field of AI (Bishop, 2018).

In Hong Kong, Innovation and Technology Bureau of The Government of the Hong Kong Special Administrative Region also announced the Smart City Blueprint on December 2017 (OGCIO, 2017). Although AI is already in use in thousands of companies around the world, most big opportunities have not yet been tapped (Brynjolfsson & McAfee, 2017).

Vocational and Professional Education and Training (VPET) is one of the major sources to provide frontline workforce to the market. In the Information Technology (IT) industry of Hong Kong, it is showing that there is a constant manpower shortage at this educational level in the coming years (CITTD, 2016). Together with the promotion work on VPET IT education, smart component should also be introduced to the curriculum to provide not only in quantity, but also in quality of the related workforce to the market.

Based on the popularity of the AI applications, the many possible development directions and the expected to be one of the key skills of the IT graduates from VPET, this paper proposes to introduce the AI component to the curriculum of the current VPET IT education. AI is a very broad field and the scope of AI includes reasoning, knowledge representation, computation, symbolic representation and cognitive science, etc. For the IT learners from VPET, instead of teaching them the mathematical proofs of those
algorithms or the detail theoretical background of AI like undergraduate Computer Sciences degree programmes (Russell & Norvig, 2015; Kumar, 1998), it is expected that the teaching of AI should be focused on the application level of tools and algorithms. We will first discuss on the expected learning outcomes and the key learning contents. Then, the tools and development environment will be recommended. The essential backgrounds of the targeted learners will then be suggested. Case studies have been conducted to lead IT learners from VPET to develop projects with AI features to evaluate their capability to master the skill of building applications with AI features with appropriate guidance. Finally, we will conclude our proposal and study, and suggest future development of the AI education in VPET.

The Expected Learning Outcomes and Key Learning Contents

As mentioned, the mathematical proofs of the AI algorithms and the detail theoretical background of AI is not expected to be the main focus on AI education for IT learners from VPET. Instead, it is expected that the teaching of AI should be focused on the application level of tools and algorithms. The corresponding curriculum is expected to equip the learners with:

- the knowledge in the key areas of AI;
- the ability to understand and compare the functionalities and use cases of basic AI algorithms;
- analyze and apply appropriate Machine Learning (ML) APIs based on a set of business and technical requirements; and
- design and develop applications with basic AI features.

To achieve these learning outcomes, the proposed key learning contents of subject should include four main learning contents. They are (1) Overview of AI, (2) Current Trends and Applications, (3) Basic ML Algorithms, and (4) Introduction to Artificial Neural Networks and Deep Learning.

As a fundamental background, the different definitions and scopes of AI should be introduced to the learners. Also, the history and evolution of the field, the corresponding ethical issues when AI becomes popular and also the latest development and future expectation are the solid-base literature the learners should come across. Different categories of IA such as the strong and weak IA, the relationship of AI, ML (Mohammed et al., 2017) and Deep Learning (Patterson & Gibson, 2017) as shown in Fig. 1, and different types of IA technologies should also be introduced to the learners. As a starting point, the demonstration on playing board game (e.g. chess) is a good example to demonstrate the basic approach on solving problem using AI.

To equip the learners with the essential skills to development applications which embedded with AI features, the basic concepts on the current popular AI technologies on visual / image recognition, Natural Language Processing (NLP) / translation, Text to Speech / Speech to Text and conversation (Chatbot) should be introduced to the learners. More importantly, practical exercises should be included to guide the learners to build prototypes using the related online APIs.

Nowadays, ML is the core components in the field of AI, different types of learning algorithms (i.e. Supervised Learning Algorithms, Unsupervised Learning Algorithms and Reinforcement Learning), the roles of data, the skills on data preprocessing and feature engineering are also important knowledge that learners should be captured.

As Deep Learning (Artificial Neural Network) is the most powerful approach and dominated in the field of ML, the basic concept, general architecture and the usages of typical deep learning models (e.g. Convolutional neural network and Recurrent neural network) should also be introduced to the learners. With the available of the development environment / frameworks, it is not difficult for the IT learners from VPET, who may not have strong mathematical background, to develop Deep Learning solutions according to different use cases. In addition, it is necessary to introduce the approaches to scale up the deep learning architecture to reduce the training time when tackling with large volume of data.

Unlike traditional undergraduate Computer Sciences degree programmes that the main focus is on introducing the learners with the theories and algorithms through mass lectures, it is expected that the AI education in VPET will be practical-oriented through hands-on laboratory workshops, demonstration and project-based learning. Lecture classes will only be served as the supportive role to give the basic background and concepts to the learners. In addition, workshop exercises, assignment and project should contribute to the major assessment components instead of written examination to reflect the level of practical skills of the learners obtained through the learning process.
Recommended Tools and Development Environment

The curriculum design in the previous section is based on the available tools to assist the learning process. In this section, the common online APIs, which are provided by the world-class IT enterprises, for AI development and the famous ML development frameworks will be given and suggested if appropriated.

Available Online AI APIs

Many world-class IT enterprises developed online AI APIs and these APIs are available on their corresponding cloud platforms. These APIs are considered as Machine Learning as a Service (MLaaS). They include: Machine Learning on AWS by Amazon (https://aws.amazon.com/machine-learning/), Google Cloud Platform (https://cloud.google.com/), IBM Cloud (previously called Bluemix, https://www.ibm.com/cloud/), and Cognitive Services by Microsoft Azure (https://azure.microsoft.com/en-us/services/cognitive-services/).

There exist many types of AI APIs while four of them are proposed to be introduced to the VPET education due to their popularity and maturity. They are visual/image recognition, Natural Language Processing (e.g. extract information, sentiment analysis, and translation), Text to Speech/Speech to Text, and conversation (i.e. chatbot). Table I lists out the corresponding APIs from the mentioned IT enterprises.

Table I. Common AI related APIs / MLaaS

<table>
<thead>
<tr>
<th><strong>Visual Recognition</strong></th>
<th><strong>Natural Language Processing</strong></th>
<th><strong>Text to Speech / Speech to Text</strong></th>
<th><strong>Conversation (Chatbot)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Amazon Rekognition Image</td>
<td>Amazon Comprehend / Translate</td>
<td>Amazon Transcribe / Polly</td>
<td>Amazon Lex</td>
</tr>
<tr>
<td>Google Vision API</td>
<td>Google Natural Language API / Translation API</td>
<td>Google Speech API</td>
<td>Google Dialogflow</td>
</tr>
<tr>
<td>IBM Watson Visual Recognition</td>
<td>IBM Watson Natural Language Classifier / Watson Language Translator</td>
<td>IBM Watson Speech to Text / Watson Text to Speech</td>
<td>IBM Watson Assistant</td>
</tr>
<tr>
<td>Microsoft Computer Vision</td>
<td>Microsoft Text Analytics / Speech Translation</td>
<td>Microsoft Speech to Text / Text to Speech</td>
<td>Microsoft Azure Bot Service</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Common ML Development Frameworks</strong></th>
</tr>
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<tbody>
<tr>
<td>Caffe UC Berkeley</td>
</tr>
<tr>
<td>Chainer Preferred Networks</td>
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<tr>
<td>Deeplearning4j Skymind</td>
</tr>
<tr>
<td>MXNet Apache Software Foundation</td>
</tr>
<tr>
<td>PaddlePaddle Baidu</td>
</tr>
<tr>
<td>TensorFlow Google</td>
</tr>
<tr>
<td>Theano University of Montreal</td>
</tr>
<tr>
<td>Torch Ronan, Soumith (Facebook) Clement (Twitter) and Koray (Google)</td>
</tr>
</tbody>
</table>

Among these frameworks, TensorFlow (Hope, 2017) is the most recommended framework here. Besides it is the framework proposed by the IT giant, Google, with full documentation and walkthroughs, it is the most popular ML framework in the market as shown by all the rankings (i.e. stars, fork, issue and pull request) in GitHub (GitHub, 2016). Also, it has already been adopted by many IT and non-IT enterprises like Airbus, Twitter, IBM, and others mainly due to its highly flexible system architecture.
However, the TensorFlow interface may be a little bit difficult for the beginners to start with due to it is a low-level library and the concept on the tensor and flow may be difficult to understand. Therefore, it is proposed to start the learning process through the use of a lightweight, easy to use and straightforward library, Keras (https://keras.io/). It provides a simplistic interface for the purpose of quick prototyping by constructing deep learning models that can work with TensorFlow. It can even build a simple deep learning model by only a few lines of code. By accumulating experience on using Keras, the learners can transfer their skill learnt smoothly to develop more complex and highly customized deep learning models using TensorFlow.

**Essential Background of the Learners**

It is no doubt that programming skill is the fundamental skill the learners should be equipped with so that they can make use of the tools (i.e. APIs) and ML development frameworks effectively. Although most of the mentioned APIs support more than one programming languages, Python (https://www.python.org/) is the preferable language because of its simplicity and easy coding behaviour (Tectitic Administrator, 2018). Python is also an open source and modular programming language with strong community support and extensive libraries. It is also the fastest growing programming language in 2018 (Heath, 2018). It provides abundant useful libraries for AI application development such as NumPy and SciPy for scientific computing (http://www.numpy.org/ and https://www.scipy.org/), Pandas for data analysis (https://pandas.pydata.org/) and scikit-learn for data mining (http://scikit-learn.org/). The suggested ML development frameworks in previous section are also Python-based and providing supporting interface (Chollet, 2018).

In addition, the manipulation of Javascript Object Notation (JSON, https://www.json.org/) is another key skill the learners should be equipped. JSON is a lightweight data-interchange format. Most of the mentioned APIs use JSON as the interface for data exchange especially on returning the results.

Data is the king in the ML paradigm. Large data set is always preferred to serve as the training data. To handle these kinds of Big Data, which have the properties of 3Vs (i.e. volume, variety and velocity), it is a benefit if the learners have prior knowledge on some kinds of Big Data frameworks like Hadoop, Spark, Cassandra or MongoDB.

Furthermore, ML always involves a long training process. To accelerate this process, some background knowledge on the computer architecture especially on the role of Graphical Processing Unit (GPU) and parallel computing is an advantage of the learners to deal with the scalability issue.

In summary, Python programming and manipulation of JSON should be essential skills for the learners to pick up the technical skills to build AI applications while the concepts on Big Data frameworks and computer architecture will help them to better learn the advanced AI operations.

**Case Studies**

To further observe if the current IT learners from VPET have the capability to learn AI and adopt it in application development through appropriate guidance, projects with AI features required are proposed to a few groups of learners (4 learners in a group) in the 2018/19 academic year to serve as their topics of the final year projects. In this section, two cases are shared to describe their learning process and the final deliverables.

**Case One – AI Travel Planner**

One group of the learners discovered that although there are many online travel planner applications to help travelers plan their trip, those applications cannot provide the traveler with a good travel plan to maximize their time. To resolve the current problem, the group decided to develop an AI travel planner which provides the users with a personalized travel plan. The system predicts the preference from the user personal information and provides a personalized travel plan.

The learners made use of AI on the prediction of user travel preference. And the trip plan generation relies on the prediction result. To achieve this, the learners used Keras to build a deep learning prediction module by inputting 50000 travel preferences. After that, the model was evaluated by cross-validation using the Python machine learning library scikit-learn. Due to the simple and straightforward design of Keras and the background of the learners, they have demonstrated their capability to complete the programme within a hundred line of codes by appropriate guidance from the supervisor and self-learning.

Throughout the development cycle, the major problem encountered by the learners was the source of data. There are no public data of people’s travel preference. To solve the problem, the learners manually converted the data from existing travel review portal into traveler preferences. In addition, the learners developed a data collection portal to collect data as illustrated in Fig. 2.

At the end stage of the project, the learners developed a travel planner mobile application (Fig. 3a). The application uses the trained prediction model to predict the user’s travel preference based on his/her gender, age, nationality, educational level and income. The predicted travel preference helps the trip plan generator to filter suitable attractions, allocate the portion of different kinds of visiting spot. A satisfactory travel plan is generated accordingly (Fig. 3b).
Case Two - Eldventure

In Hong Kong, there is a sharp growth in the elderly population. Another group of IT learners also from the final year study of VPET focuses on the importance to the health of elderly and aims to provide them a happiness in life. As long as smartphones become popular nowadays, mobile apps are a huge opportunity to offer special services and bring convenience to the elderly. The group found that the elderly may willing to share their past stories and experience with others. Thus, the learners decided to develop a platform to let the elderly to share their stories and broaden their social life.

To make the platform friendly to the elderly, the project consists of speech recognition and key phrase extraction features. To the learners, they want to apply the technology instead of building the features from scratch. Thus, they integrated the system with third-party services.

During the development, the learners evaluated similar APIs from different IT enterprises. Because of the specific need of the environment, the APIs have to be able to recognize numbers of Chinese dialects. Besides, the learners have to evaluate the Chinese analyze power for the key phrase extraction system.

After evaluation, the learners chose iFLYTEK Speech Recognition API to implement translation of speech to text due to its ability to recognize all major dialects of Chinese Language. In addition, the learners applied the Cognitive Services by Microsoft Azure. They use the Text Analytics (Chinese) API for extracting key phrases from the translation.

Finally, the learners developed a Mass Open Online Course (MOOC) platform named Eldventure. The platform lets the elderly record their life stories (Fig. 4a). The voice recording was sent to iFLYTEK speech recognition API to translate speech to text, which is shown in Fig. 4b. The learners demonstrated that they have no difficult to adopt those online AI APIs to develop the mobile application because they have already learnt the skill to use online APIs.
Conclusions

In this paper, it is proposed to introduce the AI component to the curriculum for the IT learners from VPET. The proposed learning outcomes and key learning contents, tools and development environment recommended, and the essential background of the learners are described in detail. Two case studies are presented and they already demonstrated that the targeted learners are ready to take up this challenge.

AI is a large field and it includes multiple disciplines and a variety of tools and platforms. It is more than programming languages, tools and algorithms and can be adopted across different domains and industries. Therefore, studying AI opens a world of opportunities to not only IT learners but all the learners from VPET. In the shortcoming future, it is necessary to further investigate the feasibility to develop a generic AI curriculum to introduce AI to all the learners from different disciplines of VPET. At an entry level, the learners should learn the basic idea on the key areas of AI, understand the systems that they interact with on a daily basis and even have a taste on building simple AI-embedded application prototype with the assist of tools. The ability to anticipate and prepare for the future skills will be one of the critical factors for the success of VPET.

References


USING A MACHINE LEARNING APPROACH TO EVALUATE THE EFFECTIVENESS OF LEARNINGANTS ON STUDENTS’ LEARNING

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Abstract

Evaluation plays an important role in enhancing our understanding of, and ultimately, improving different aspects of the teaching-learning process. It is essential if we want to systematically judge the worth of a new potentially innovative practice, as it provides valuable feedback on the design, implementation and effectiveness of any learning tool or activity in terms of impacting student learning. Most importantly, it provides educators with specific feedback on the effectiveness of a particular learning tool or activity in achieving the desired learning outcomes. To conduct a proper evaluation, the gold-standard of a quantitative study is setting up of a randomized controlled trial. However, randomized clinical-like trials are often not viable in educational contexts as valuable educators’ resources are typically directed to actual teaching activities rather than ‘experimenting’ on students.

In this research, we carried out a study to evaluate the effectiveness of a learning tool on students’ learning using a machine learning approach. LearningANTS, a system that supports differentiated learning and learning analytics, was deployed in an engineering mathematics module at Singapore Polytechnic. After the semester was over, possible factors that could contribute to students’ initial level of preparation for the module were identified. Taking into consideration these factors, the effectiveness of LearningANTS on students’ learning in the module was then evaluated by using a machine learning algorithm to construct a predictive model to predict students’ performance in the module. Learning gain in the module was then determined by computing each student’s Added Value, which was calculated by taking the difference of the student’s Predicted Score from his Actual Score.

Between the group who had access to the system referred to as the “Treatment Group” and those who did not have access to the system referred to as the “Control Group”, it was found that the mean Added Value of the Treatment Group was higher than the mean Added Value of the Control Group and this was statistically significant. This result suggested that students who had access to LearningANTS had higher learning gains when compared to those who did not.

While the results of this research study show that LearningANTS improves students’ learning of the module, further research can be conducted to investigate whether the conclusion is consistent when a similar research is done on a different batch of students or on a different subject matter. This will provide a more comprehensive and reliable evaluation of LearningANTS.

Keywords: Symbolic regression, machine learning, differentiated learning, learning analytics, predictive modelling, LearningANTS

Introduction

It is common practice for educators to try out new pedagogies or implement new learning tools/activities in the classroom. Instead of rolling out the pedagogy or tool/activity in all classes of a module, educators often do a pilot study on a smaller scale to test its effectiveness. In a smaller scale pilot, it is easier for the educator to manage the logistics while gathering information as well as mitigate surprises during the study. To ascertain the benefits and drawbacks brought about by such education innovation, a well-planned evaluation therefore plays an important role as it helps educators gain insights into whether a particular intervention benefits students’ learning. As Kemmis (1989) identified, evaluation is the process of delineating, obtaining and providing information useful for making decisions and judgements about educational programmes and curriculum.

To conduct a proper evaluation, the gold-standard of a quantitative study is the setting up of a randomized controlled trial. However, randomized clinical-like trials are often not viable in educational contexts as valuable educators’ resources are typically directed to actual teaching activities rather than ‘experimenting’ on students.
If a random placement into a treatment and a control group is impossible, a simple solution for educators conducting a quasi-experiment is to compare batches (Emke, 2015; and Sumarno et al. 2017). While not questioning the validity of findings of Emke (2015), we argue that their research methodology is not transferrable to an experiment for teaching a mathematics course at the tertiary level in Singapore. Indeed, if a Singapore-based math educator were to directly compare results of two batches, the study would be contaminated by a selection bias called forth by at least two causes:

(1) Difficulty of final exams in mathematics can vary significantly across years. If students’ scores were higher in one year than in the year before, one possible explanation could be that the paper was easier.

(2) Quality of intake varies over the years. For instance, a higher birth rate in dragon years (see Yip, 2002), results in greater competition for university placement.

Selection bias is a persistent, and often hidden, problem in educational research. It is the primary obstacle standing in between increasingly available large education datasets and the ability to make valid causal inferences to inform policymaking, research, and practice (Stuart, 2010).

A clever way to work around the selection bias was implemented in Hardy (2014). In order to eliminate the selection bias, the authors conducted a preliminary concept test in the beginning of each class, divided the whole cohort into four levels according to the test results and then analysed the four levels separately. However, the method of control for the initial level of students used by Hardy (2014) is less systematic and requires more data as compared to the method based on symbolic regression in Duzhin et al. (2018).

Another common technique of evaluating pedagogical efficacy is concept inventory, modelled after difference-in-differences in economics. A concept inventory is a special test on the understanding of basic concepts given to students before and after the course. The difference between post-scores and pre-scores is a measure of the overall pedagogical efficacy of the course. This technique is usually applied in large studies, such as Crouch (2001) and Beichner (2007).

While concept inventories can be extremely useful to measure the effectiveness of a course as a whole, this technique has some very serious limitations:

(1) It's hard to attribute the gain in a concept test to a particular teaching approach or an instructional tool utilized by the educator.

(2) Concept inventories involve extra tests that need to be administered for the sake of research, i.e., they disrupt the normal teaching and learning process.

Summarizing all the above, we see that traditional experiment designs in education are suitable for education researchers rather than practitioners who are mainly interested in finding out whether their teaching approaches are effective in their classroom for their students. For instance, studies conducted by education practitioners without proper training in statistics and experiment design are often contaminated by selection bias and are not trustworthy while studies conducted by professional researchers are scarce and chances are that a practitioner won’t be able to find a relevant one.

**Machine learning algorithms for predicting students’ grades**

A number of authors have developed machine learning algorithms to assist educators. The central theme of this research is predicting students’ performance – see, for example, Lykourentzou (2009), Zafra (2009), Cortez (2008), and Xu (2017). There even exist prototypes of software for predicting students’ performance – see Livieris (2016).

The problem of predicting a response variable’s value from a number of observations of predictors and the response variable is the central question of supervised machine learning. A number of algorithms for supervised machine learning are known – see, for example, Friedman (2001) or any other textbook on machine learning. Among a variety of algorithms, such as kth nearest neighbour, random forest, support vector machine, artificial neural network etc., we chose symbolic regression for our study.

To justify the choice of symbolic regression, let us discuss the desired properties of a machine learning algorithm for predicting students’ scores from their initial level:

(1) The response variable is numeric, i.e., we need regression rather than classification.

(2) Educational datasets are small and therefore algorithms that are prone to overfitting would not be a good choice since they require splitting the data into training and test datasets, i.e., they do not work well for small datasets.

(3) Educational datasets usually have missing values (due to students skipping a test).

(4) It is desirable to have transparent models so as to be able to only select relevant variables and to check whether the models make sense.

A strong predictive power is not necessary, for if students’ performance could be predicted from initial level with high accuracy, then the choice of learning activities would not matter and the whole idea of experimenting with pedagogy would be futile.

Table 1 summarizes (Friedman, 2001) properties of five popular machine learning algorithms and clearly
shows why symbolic regression is, indeed, the most reasonable choice.

<table>
<thead>
<tr>
<th>Symbolic regression</th>
<th>Predictive power</th>
<th>k th nearest neighbor</th>
<th>Randon m forest</th>
<th>SVM</th>
<th>Neural network</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predictive power</td>
<td>weak</td>
<td>weak</td>
<td>strong</td>
<td>strong</td>
<td>strong</td>
</tr>
<tr>
<td>Handles missing values</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>Small data sets</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Transparent models</td>
<td>yes</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>no</td>
</tr>
</tbody>
</table>

Table 1: Desired properties of popular machine learning algorithms.

Furthermore, among various available implementations of symbolic regression we chose DataModeler – an add-on to Wolfram Mathematica.

Our methodology is based on predicting students’ grades with the purpose of control for selection bias in a natural experiment in education. (Duzhin et al., 2018).

Case Study

In this research, we carried out a study to evaluate the effectiveness of a learning tool on students’ learning using symbolic regression. LearningANTS, a system that supports differentiated learning and learning analytics, was deployed in an engineering mathematics module at Singapore Polytechnic. (Chan et al., 2017)

Four recap topics on Differentiation were identified - Sum and Difference Rule, Chain Rule, Product Rule, and Quotient Rule - and rolled out in the system. Students taking this module had already covered these topics in a pre-requisite module. Students would need to make use of what they had learnt in the pre-requisite module for the new differentiation topics covered in the current module.

Students had access to the system right up to the day before their final exam. At the end of the semester, 89 students used the system. We then proceeded to determine if there is any value-add to students’ performance in having introduced such a system to the module by comparing between the group who had access to the system referred to as the “Treatment Group” and those who did not have access to the system referred to as the “Control Group”.

To allow for comparison between the two groups, we introduced a variable termed “Added Value”, which is computed using the expression:

\[ \text{Added Value} = \text{Actual Score} - \text{Predicted Score} \]

“Actual Score” refers to the final score that students obtained for this module, while “Predicted Score” is what a student was expected to score for this module based on a statistical model built using the test and exams scores of his previous mathematics module and the scores he obtained for his mid-semester test of the said module.

By calculating Added Value, we were able to control for much of the selection bias because Added Value can’t be contributed by factors such as motivation, diligence, and talent since these factors would have affected the students’ initial level in the same way as they would have affected their performance in the said module.

Data

A sample of the data is shown in Table 2. It shows students’ scores together with a categorical variable indicating whether the student belonged to the Control Group or the Treatment Group. The summary of the data is shown in Figure 1.

<table>
<thead>
<tr>
<th>ID</th>
<th>Group</th>
<th>p1</th>
<th>p2</th>
<th>p3</th>
<th>p4</th>
<th>p5</th>
<th>v1</th>
</tr>
</thead>
<tbody>
<tr>
<td>B0083</td>
<td>Control</td>
<td>56</td>
<td>58</td>
<td>65</td>
<td>2.68</td>
<td>68</td>
<td>47</td>
</tr>
<tr>
<td>B0084</td>
<td>Control</td>
<td>89</td>
<td>82</td>
<td>87</td>
<td>3.91</td>
<td>72</td>
<td>66</td>
</tr>
<tr>
<td>B0085</td>
<td>Control</td>
<td>67</td>
<td>81</td>
<td>78</td>
<td>3.73</td>
<td>83</td>
<td>75</td>
</tr>
<tr>
<td>B0086</td>
<td>Control</td>
<td>83</td>
<td>67</td>
<td>71</td>
<td>2.5</td>
<td>33</td>
<td>20</td>
</tr>
<tr>
<td>C0001</td>
<td>Treatment</td>
<td>84</td>
<td>73</td>
<td>76</td>
<td>2.88</td>
<td>78</td>
<td>70</td>
</tr>
<tr>
<td>C0002</td>
<td>Treatment</td>
<td>65</td>
<td>66</td>
<td>67</td>
<td>2.29</td>
<td>61</td>
<td>67</td>
</tr>
<tr>
<td>C0003</td>
<td>Treatment</td>
<td>72</td>
<td>68</td>
<td>70</td>
<td>3.13</td>
<td>64</td>
<td>46</td>
</tr>
</tbody>
</table>

Table 2: A sample of the data. Here, “ID” refers to the student ID, “group” is either Control Group / Treatment Group; “p1”, “p2”, “p3”, “p4”, “p5” are predictors - results of tests indicating the students’ initial level; “v1” is the exam score.

Referring to Table 3, it appears that the Treatment Group is, on average, weaker than the Control Group since the mean scores of all the predictors, i.e., p1, p2, p3, p4 and p4, are lower than those of the Control Group. Interestingly, the Treatment Group achieved a higher mean exam score (see Mean v1) when compared to the Control Group.

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean p1</th>
<th>Mean p2</th>
<th>Mean p3</th>
<th>Mean p4</th>
<th>Mean p5</th>
<th>Mean v1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>60.38</td>
<td>67.57</td>
<td>69.24</td>
<td>3.07</td>
<td>61.55</td>
<td>52.47</td>
</tr>
<tr>
<td>Treatment</td>
<td>55.98</td>
<td>66.06</td>
<td>67.37</td>
<td>3.07</td>
<td>59.37</td>
<td>56.25</td>
</tr>
</tbody>
</table>

Table 3: The mean of each of the metrics in the Control Group and in the Treatment Group.
Modelling

We applied symbolic regression and constructed the models that predicted the response variable v1 (exam score) from predictors p1, p2, p3, p4, and p5 – metrics of students’ initial level. Refer to Figure 2 for the models. Each model is an explicit formula that approximates the response variable in terms of the predictors. Every point in Figure 2 represents such a formula on the Complexity-Accuracy plane. Models that are unsurpassed by either accuracy or complexity form the so-called Pareto front. Models that are too complex or too imprecise are discarded. Figure 4 shows a few models selected to form the model ensemble that is actually used for prediction.

For models included into the ensemble, we have $1 - R^2 \approx 0.42$ or $R \approx 0.76$, i.e., the accuracy of the models is about 76%. There were 7 statistical outliers – 2 students whose actual score far exceeded the prediction and 5 students whose actual score fell far below the prediction, as shown in Figure 3.

Note that only the variables p3, p4, and p5 appeared in the models. This result suggests that p1 and p2 were not relevant and therefore could be discarded. For instance, one could check if the response variable is an increasing function of each of the predictors, which makes sense in education. This happens to actually be the case – the ensemble’s prediction is, indeed, an increasing function of each of the variables p3, p4, and p5.

Comparing non-randomly assigned groups

Recall the following definition:

\[
\text{Added Value} = \text{Actual Score} - \text{Predicted Score}
\]

Thus Added Value provides a means to consider students’ initial level of preparation. Whisker charts of added values and raw exam scores in the Treatment and Control groups are shown in Figure 5.

Table 4 shows the mean and the median raw scores and Added Values in the Treatment Group and Control Group. We have tested the following four hypotheses:

1. The mean raw scores in the Treatment Group is not equal to that in the Control Group vs the null hypotheses that they are equal.
2. The mean Added Values in the Treatment Group is not equal to that in the Control Group vs the null hypotheses that they are equal.
3. The median raw scores in the Treatment Group is not equal to that in the Control Group vs the null hypotheses that they are equal.
4. The median Added Values in the Treatment Group is not equal to that in the Control Group vs the null hypotheses that they are equal.

Note that we have applied the t-Test for means and the Mann-Whitney u-Test for medians. From result shown in Table 4, we can conclude that hypothesis should be accepted with the usual significance level of 0.05 if we look at Added Values but should be rejected if we look at raw exam scores. It means that the machine-learning based method of controlling for initial level of students’ preparation provided means for improving statistical significance of the findings.
Results and Discussion

We have seen from Table 4 and Figure 5 that the intervention have been, on the average, effective for the Treatment Group. This suggested that students who had access to LearningANTS had higher learning gains compared to those who did not.

Diving deeper into the results show that there are always students whose performance exceeded expectation (positive Added Value) and there are always students whose performance falls behind expectation (negative Added Value). This could be explained by a variety of factors, such as personal affection towards the teacher, the subject or the way the subject is taught or, on the contrary, by family issues that distracted the student from studies in that particular semester.

As shown in Table 4 and Figure 5, the increase in the average score is mainly due to the following fact: while there were students who underperformed the prediction in both the Control Group and the Treatment Group, such “under-performers” in the treatment group underperformed by a smaller margin as compared to their peers in the control group. In colloquial terms, the intervention helped students who could not or did not want to devote sufficient time to studying for this course. They still did not perform according to their level, but it could have been worse without the intervention.

Conclusion

While the results of this research study suggest that LearningANTS improves students’ learning of the module, further research can be conducted to investigate whether the conclusion is consistent when a similar research is done on a different batch of students or on a different subject matter. This will provide a more comprehensive and reliable evaluation of LearningANTS.

References


PROPOSAL FOR REDUCING PATTERN POSITION ALIGNMENT ERROR OF A SIMPLIFIED PHOTO LITHOGRAPHY METHOD FOR EDUCATION


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Abstract

Reduction of alignment error (AE) was studied for a simplified lithography process that was named “Alignment Less Lithography process (ALL)” that can be used make semiconductor devices in the average science laboratory. Heretofore, ALL had been proposed and successfully demonstrated to make a simplified silicon bipolar transistor and MOS FET. However, the typical average AE among the circuit patterns was as large as approximately 50μm. It is recognized that the AE has to be reduced for making integrated circuits (IC), since a number of photo-masks are used. It is expected that the AE can be reduced to zero if the set of photo-masks whose physical sizes are exactly the same can be prepared, and the circuit pattern position on each photo-mask was also exactly the same. Furthermore, if the substrate can also be set at the exact same position every time, perfect pattern matching of the IC can be achieved without using sophisticated apparatus, such as an XYZθ stage. Photo-masks were designed and printed on plastic transparent sheets for over head projectors. Precise physical size control of each photo-mask was achieved by polishing with waterproof abrasive cloth with nanometer sized polishing materials. A simple alignment jig was prepared for the photo-mask setting by applying the concept of a mechanical pin alignment method. As for the results, it was successfully demonstrated that the AE was reduced to within 10μm with approximately 200μm resolution. In addition, the distribution of the positioning was also successfully reduced by a specially designed simple transportable UV exposure system. It is understood that this method will be useful for cultivating scientific minds for engineering education, as the educator can prepare a program for students to learn how to make an idea and how to solve the problem through reliving achievements of our predecessors, such as the world’s first IC by using this method

Keywords: Photo Lithography, Alignment, Fabrication Process, Semiconductor Device

Introduction

We have been studying to develop a totally simplified fabrication process that can be applied to a variety of semiconductor device fabrication to help students obtain deep understanding of semiconductor device physics through their own practical experience. A simplified method has been considered to establish a device fabrication laboratory that has been named “A Nanotechnology Platform Established for the Normal Science Laboratory” in average educational organizations. We understand that there are three important fabrication processes, which are “fabrication of the thin films”, “control method of dopant introduction” and “lithography methods”.

Figure 1 Hypothesis of the Alignment Less Lithography (ALL) Process
It is understood that basically, planar type semiconductor devices are fabricated by this set of processes, even in new state of the art devices, or for even the world’s first integrated circuit. Therefore, it is most important to simplify these three processes. We have successfully achieved simplification of the control method of dopant introduction by the thermal diffusions of the Phosphorus and Boron using the Phosphorus Silicate Glass (PSG) and Borosilicate Glass (BSG) thin films, respectively under a normal air environment. Silicon oxide thin film as the insulator for a MOS device fabricated under normal air environment was also proposed and successfully demonstrated. In addition, an electrode fabricated by the Ag past patterned by a screen printing method under a normal air environment that can perform the same as a thin film electrode prepared using a vacuum apparatus was also proposed and demonstrated.

Therefore, if we achieve the simplification of the lithography process, we can finally achieve a simplified nanotech platform for the average science laboratory. A method was proposed and demonstrated to achieve simplification of the lithography process using transparent plastic sheets for overhead projectors (OHP sheet) in which the device patterns were printed by laser printer. However, the relatively large value of the alignment error of the photo-mask pattern has remained a problem.

In this study, a method to determine the positions of the circuit patterns exactly the same on the OHP photo-mask set was proposed and that by lapping and polishing the mask edges, and it would be possible to eliminate the position error of the patterns to near zero.

**Hypothesis of Alignment-Less Lithography**

In general, the device circuit pattern is divided into several parts. Each of the parts are fabricated by the lithography process. The total device circuit patterns are overlapped and laminated onto the substrate in the order shown in Fig.1(a).

The photolithography process is the process for making the circuit pattern using a photo resist which is a specially designed polymer including a photo sensitizer, before the fabrication of the part of the circuit pattern by the etching process. Therefore, the following two position alignments are required. The first is “absolute pattern alignment” to achieve setting of the photo resist pattern at the target position on the substrate and the second, “relative position alignment” to achieve setting the photo resist patterns to coincide exactly where they are superimposed on the circuit patterns.

During the traditional integrated circuit fabrication process, a XYZθ stage is used to achieve both of these demands at the same time. However, it is difficult for the average educational organization to introduce such specially made equipment as same as the measurement apparatus that have been equipped and have been used in a normal experimental class room, for example, PC’s, multi-meters, breadboards, etc. In addition, it is also difficult to prepare a glass photo-mask set which has been commonly using to make photo resist patterns with the stage.

Therefore, to achieve a simplification of the lithography process, the two simplifications which are the simplification of the lithography apparatus and the simple photo-mask preparation method, design, fabrication, and revising the photo-mask set are required as the most important issues. It means that the photo-mask set fabrication from pattern design, fabrication and revising to be finished easy and quickly under limited circumstances by students themselves. To achieve the simplification of the photo lithography process for the fabrication of the simplified device fabrication process, it was recognized in “absolute pattern alignment” that the device circuit pattern set at the center of the silicon substrate without any circuit pattern rotation error is not necessary, and that “relative position alignment” is only necessary for the device fabrication.

Under this understanding, if the positions of all of the circuit patterns on the photo-masks is designed and fabricated very accurately and the physical size of the photo-mask substrates also are fabricated to the exact same size, in addition, the silicon substrate and the photo-mask can be set to the exact the same position every time, the relative position alignment between the each of the circuit patterns on the photo-masks and the circuit patterns that have been already fabricated on the silicon substrate is achieved with no alignment error in principle.

This hypothesis means that the sophisticated XYZθ stage can be avoided, and the lithography apparatus can be drastically simplified. It means that the simplified photo-mask alignment can be achieved to only focus on the mechanical positioning of the substrate and the photo-masks. The positioning errors of $\Delta r = r_a - r_i$, $\Delta \theta = \theta_a - \theta_i$, $\Delta \theta_{MC}$, $\Delta \theta_{SS}$ could remain. However, it is recognized that it is not an important issue, because it only causes an offset of the whole circuit pattern on the silicon substrate.

![Figure 2 Photo-mask making process](image-url)
Photo-mask was arranged accurately by CAD function of the software. X and Y can be determined to cut the edges of the substrate. Firstly, the circuit pattern for the commercially available normal laser printer. The photo-mask by cutting, exactly the same. The term X horizontal edges of the photo-mask and the pattern and Y here means the distances between the vertical and point to achieve two distances X and Y of each of the issue of the fabrication, i.e., it is the most important pattern among the photo-masks is recognized as the key perfect physical position matching of the divided circuit the circuit patterns for the photo-masks were printed by testing and revising of the photo-mask set to make it establish the circumstance of the design, fabrication, designed and revised using the CAD function included own design and by oneself. The mask patterns were easily and quickly in any time at anywhere by one’s Point(PP)” by Microsoft corporation. The students can (OHP sheet) was used as the photo-mask blanks. And the transparent plastic sheet for the over head projector use, in the class room, or in anytime and at anywhere. the practise use for the programming and the simulation fabrication using their own PC or the PC prepared for learn all of the processes regarding to the photo-mask process about the photo-mask making. It is necessary to this hypothesis. To achieve this photo-mask fabrication, it expected that it will make the physical position error compensation of the circuit pattern on each of the photo-mask possible through the polishing of the photo-mask itself. However, it is difficult to apply this method to the traditional glass photo-mask. Therefore, we propose to use plastic transparent sheets on which the circuit patterns are printed to make the polishing possible.

Experimental Method

Fig. 2 shows a brief overview of the fabrication process about the photo-mask making. It is necessary to establish the circumstance of the design, fabrication, testing and revising of the photo-mask set to make it easily and quickly in any time at anywhere by one’s own design and by oneself. The mask patterns were designed and revised using the CAD function included in the common presentation software, like “Power Point(PP)” by Microsoft corporation. The students can learn all of the processes regarding to the photo-mask fabrication using their own PC or the PC prepared for the practise use for the programming and the simulation use, in the class room, or in anytime and at anywhere. The transparent plastic sheet for the over head projector (OHP sheet) was used as the photo-mask blanks. And the circuit patterns for the photo-masks were printed by a commercially available normal laser printer. The perfect physical position matching of the divided circuit pattern among the photo-masks is recognized as the key issue of the fabrication, i.e., it is the most important point to achieve two distances X and Y of each of the photo-mask by cutting, exactly the same. The term X and Y here means the distances between the vertical and horizontal edges of the photo-mask and the pattern edges of the substrate. Firstly, the circuit pattern for the photo-mask was arranged accurately by CAD function of the software. X and Y can be determined to cut the cutting guide line, which is the minimum size to print by the laser printer. The printed circuit pattern on the OHP sheet was cut by the simple method to focus on the simplification of the process, for example, hand work using several types of the knifes, cutter knife, design knife, guillotine cutter, etc. The estimated position error is measured by the optical microscope. It is estimated less than 100µm. To eliminate the remained position error, which is understood as “relative position error”, grinding and polishing method were used, and the treatment was proceeded until zero position error was achieved using the water proof abrasive papers by cut and try method with checking the actual position error using a general optical microscope and also using the travelling microscope. Approximately from 20µm to 0.5µm grain size of abrasive papers were used. It is recognized that the photo-mask set with the same relative position error can be achieved by this method. It is also very important to set the same positions for the photo-masks and the substrate at every lithography processes. In the lithography process, there are two accuracies, one is repeat accuracy and the other is overlay accuracy. It is understood that it makes the high repeat accuracy of the circuit pattern alignment in the ALL process possible, the ALL process with high accuracy of the circuit pattern alignment can be achieved, since the photo-mask set with almost no alignment error is obtained. Therefore, the pin alignment is applied to achieve the AL process was proposed, the simple mechanical alignment process was tested to achieve the high repeat accuracy without photo-mask alignment.

Figure 3 shows the schematic overview of the ALL process. The alignment jig for ALL process has double recessed stage structure to insert the photo-mask and the substrate. A substrate with photo resist coated is fitted into a deeper recessed section at the center of the jig. The photo-mask thereon is fitted into a shallower recessed section at the center of the jig. The photo-mask thereon is fitted into a shallower recessed section at the center of the jig. The alignment jig for ALL process has double recessed stage structure to insert the photo-mask and the substrate. A substrate with photo resist coated is fitted into a deeper recessed section at the center of the jig. The photo-mask thereon is fitted into a shallower recessed section at the center of the jig.
shown in the Fig.3 (b). The position and rotation errors, Δx, Δy, Δα, Δφ are remained, but they are constant value. Therefore the perfect position matching of the circuit patterns are achieved for the contact/proximity exposure methods, though the pattern are offset shown in the Fig. 1 (a). In addition, the exposure apparatus can be drastically simplified.

Fig. 4 shows an example of the alignment jig fabricated by this concept. Fig 4 (a) shows the alignment jig itself and the Fig. 4 (b) shows the condition that the substrate and the photo-mask were set at the right positions. It is recognized that the alignment of the substrate and photo-mask were successfully finished. Fig. 4 (b) shows the simplified exposure apparatus consisted by the Ultra Violet (UV) lamp which is a commercially available germicidal lamp and the simple system to determine the distance between the UV light and the jig. In general, the parallel rays are required for the exposure system to avoid decreasing the resolution. The rays from the UV lamp of the system are not parallel rays, but radiating all directions from the line spot. and the shape of the light source is rectangle-shaped pattern. The common commercially available Ultra Violet (UV) lamp was used as the light source for the exposure system. The UV light radiation is not parallel rays, but radiating all directions from the line shaped light source. It is understood that all of these are the cause to decrease a resolution of the photo resist pattern. However, the maximum resolution is approximately several tens microns in the resolution in this process. Therefore, it is expected that the influence to the resolution is negligible small in this condition.

Experimental Results

Fig 5 shows a typical fabrication result of the OHP sheet photo-mask. A series of photo-masks was printed in-line on the same sheet to be intended to the remained width of the cutting lines same after cutting in a row of the photo-masks shown in the Fig. 5(a).

Fig. 5 (b) shows cross sectional view of the photo-mask edge after cutting, grinding and polishing. The burr of the OHP sheet was generated after the cutting. It is expected to be a cause of the alignment error. There is no significant difference among the cutting methods. It was obtained that the hand cutting by simple device, such as razor, cutting knife could play an expected role in the preparation. Approximately 1µm grinding per one stroke was achieved by hand working using about 20µm grain size of the polishing water proof paper, and a mirror polishing was also achieved by using approximately 0.5µm grain size of the polishing water proof paper, respectively.

Fig 6 shows the result of ALL process by using 2 photo-masks. It was obtained that three circuit photo-mask patterns to consist the fundamental structure of the MOS FET were perfectly matched by ALL process. It was demonstrated that ALL process performs as a new simplified lithography method to the device making. The photo-mask set design and fabrication method with photo-mask polishing method to achieve the perfect pattern matching of the photo-mask.

Fig 7 shows the histogram analysis of the superimposition error using two photo-masks in ALL process by 4 average students who have no experience to handle this work. Each student performed the trial 10 times, and evaluated the superimposition error 4 points in each trial. This is the result of 160 times evaluation results. It was obtained that approximately 15% was zero error, and the standard deviation (STD) was ±40µm. However, approximately 50% was over 100µm. It is obvious that it is the result big enough to be
checked by looking and to be decided to try again. Therefore, we focused the results under ±100µm errors, and re-evaluated. As the results, the average values of superimposition error and STD were approximately 30µm and ±18µm in the vertical axis and approximately 4µm and ±24µm in the horizontal axis, respectively. The rotation error also evaluated by calculating using two data 30mm separated positions in X and Y axis. It was obtained that the rotation error was within ±0.02 degrees. It was obtained that the error in vertical axis was larger than the error in horizontal axis. This is the common result that was realized in each of the personal data. The difference of the grinding and polishing condition may be the a cause of this result.

Discussion

The alignment error was much larger than the value we expected that should be almost zero. It is expected that the position of the substrate and photo-mask may accidently be moved by the mechanical shock during the setting in the exposure process. Therefore, to avoid the influence, the tilting stage for the alignment and tilting jig shown in the Fig 8 were proposed and fabricated by 3D printer.

Furthermore, the potable light source shown in Fig 9 was proposed to avoid the jig is manually moved as shown in Fig 8. It is understood that this is unique idea using characteristics of the ALL process. These ideas make the ALL process possible without moving the jig after setting of the substrate and photo-mask to avoid the possible position error.

Fig 9 shows the evaluation result of the double exposure lithography process with ALL process using the tilted jig and the portable light source. The double exposure lithography process was applied to avoid the influence of the variation of the grinding and polishing process of the photo-mask.

The almost zero error pattern matching was demonstrated by this method as shown in the Fig 10. It is demonstrated that both two ideas are very useful for ALL process to improve the alignment error. It is demonstrated that both two ideas are very useful for ALL process to improve the alignment error.
Figure 10 Typical superimposed alignment result of ALL process with the modified setting jig and apparatus

Conclusions

To establish the semiconductor device fabrication circumstance, we named “NANO Tech Platform Established at the Average Science Laboratory”, we investigated the feasibility to apply the simplified new lithography method, "alignment-less lithography (ALL)" on the educational program. To improve the accuracy of the mask alignment, the following ideas was tested:

1. Grinding and polishing the edge of the OHP sheet photo-masks to achieve the perfect pattern arrangement on the circuit patterns among the OHP sheet photo-mask set.
2. Tilting jig and the portable UV light source for the exposure system to avoid to be generated after the setting the photo-mask dislocation.

As the result, approximately 20µm of photo-mask alignment error including about 15% of the zero alignment error and negligible small rotation error was successfully achieved without relying the skill level of the students about the lithography process. It was successfully demonstrated the usefulness of the ALL process.

It is expected that the total simplification of the device fabrication process would achieve by our simplified processes, such as impurity diffusion, fabrication of the thin films for the insulation and electrode without using vaccum aparatus under normal air environment, and this ALL process.

Furethermore, it is expected that the improvompent in each of the process can proceed, even the integrated circuits can be made by the improoved totally simplified fabrication process we proposed. And “A Nanotechnology Platform Established for the Normal Science Laboratory” would be possible to establish.

Acknowledgements

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References


Abstract

The curriculum of the Electrical Engineering (EE) Diploma in Ngee Ann Polytechnic (NP) has undergone transformative changes in recent years. This is in response to the declining students’ interest to pursue engineering, the need to stay relevant in the 21st century, and the changing education landscape. The Project-Based Learning (PrBL) approach dovetails seamlessly with engineering education as the engineering profession can hardly be practiced outside of project domains. From mass transit infrastructure and trains to energy efficient buildings, from power distribution systems to healthcare products and innovations, engineers work on projects to create, develop, value-add, and ensure that everything works to deliver quality systems, products and services to people and communities. Besides gaining technical competencies, students develop transferable skills that are highly valued by employers and industry. As students work on challenges in teams, they apply creativity, critical thinking, teamwork, communication skills, and time and project management skills, essentially simulating the real work environment they will eventually find themselves in.

EE’s curriculum reform efforts started with the focus on the horizontal integration of three Year 2 modules centred on a real-world engineering project using the Project Based Learning approach (PrBL). This approach enabled students to connect classroom instruction with real-world problem solving. It also deepened their interactions with peers and lecturers. The early indications of success of this led the team to proceed to build PrBL into the curriculum to include other levels. The implementation is such that the project focus progressively deepens in terms of openness, innovation, and complexity from level 1 to 3. The level one implementation anchors on a year 1 module, Analogue Electronics & Applications (AEA), culminating in an Arduino-based project demo on Smart Systems during the School of Engineering’s Creativity and Innovation Week. PrBL finds its fullest expression in a level-3 specialisation option, Engineering Product Development where four core modules are integrated to enable students to develop an engineering product.

Preliminary evidences show that the PrBL implementation is promising in transforming engineering education and better prepare students for the profession. Further deepening and widening of PrBL in the curriculum are vital for full transformation. However, careful planning of staff and learning resources is critical as the project pedagogy is resource intensive. Furthermore, learner-centred learning is key as instructors move away from teacher-centred to a more facilitative style of teaching.

Keywords: Project-based learning, critical thinking, engineering education, communication skills

Introduction

The world is facing a shortage of engineers across multiple industry sectors and technology areas. Singapore’s renewed focus on STEM and engineering in response to the shortage is but a reflection of the wider trend observable in other major economies, according to a report commissioned by UNESCO (Beanland and Hadgraft, 2013). The shortage of practicing engineers is of grave concern even as nations grapple with the grand challenges posed by climate change and environmental sustainability, shortage of food, clean water and renewable energy sources. In the VUCA (volatile, uncertain, complex, and ambiguous) world of the 21st century, engineering education can no longer remain business-as-usual. Educators must address the factors that turn students away from engineering, perceived as a difficult field of study with uninteresting job descriptions, unattractive career advancement and rewards (Beanland and Hadgraft, 2013).

This paper documents curriculum reform efforts undertaken by the Ngee Ann Polytechnic (NP) team for the Diploma in Electrical Engineering (EE). The team seeks to invigorate the learning of engineering and change the perceptions of engineering students especially the significant number who did not choose engineering as their top choice. Central to the curriculum change is the Project-Based Learning (PrBL) that holds much promise in getting students to engage in deep learning, gain a better appreciation for the engineering profession, and thus be better prepared for the industry. Many engineering schools in other parts of the world have adopted the PrBL approach to transform the conventional instructor-based teaching into student-centric learning; for example, Olin College of Engineering, Aalborg University, and Singapore University of Technology & Design, to name just a few.
Inspired by these trailblazers in the midst of a changing education landscape, in April 2014, Ngee Ann School of Engineering (SoE) piloted its first PrBL project linking three Year 2 modules centred on a real-world washing machine. Students implemented knowledge and skills acquired in the three modules and built sub-systems for the washing machine. Seeing an actual washing machine operate using the sub-systems designed and built by students themselves is a source of motivation for their learning. Building on this early success, the PrBL was subsequently applied to Year 1 and 3 curriculum as well. The outcomes of the initial reform efforts have been encouraging and paved the way for a more complete implementation of the PrBL approach.

**PrBL in the Electrical Engineering (EE) Curriculum**

The EE PrBL projects are real world in nature for all three years. This provides a powerful motivation for learning. Traditional engineering instruction is deductive, however, the PrBL approach is inductive (Prince and Felder, 2006); that is, a problem or project is used as an integrative driving question to facilitate the learning of one or more modules relevant to the project. In this way, learning is contextualised and meaningful to the learner.

In the curriculum for Diploma in Electrical Engineering, the PrBL is implemented with progressive scaffolding in terms of open-endedness, creativity, and complexity from Year 1 to 3. The PrBL is implemented in a more structured manner so that students are able to take on more challenging problems as they progress to higher levels. Year 1 real-world projects are simulated and scaled down to facilitate effective learning at the introductory level. Due to the simplified and approximated real-world project models, students are provided with more room to explore different innovative ideas. An overview of the PrBL implementation for the different modules from Year 1 to Year 3 is given in Table 1.

The freshman year project serves as an appetizer to induct students into the world of engineering. The challenge here is to use an interesting “hook” for the project, yet basic enough to engage all learners who are new to the course. The interesting range of sensors for year 1 Arduino control allows students to implement smart systems; these include motion sensor, ultra-sonic sensor, temperature sensor, shaft encoder, soil humidity sensor, gas sensor, and so on. Once students try their hands on such basic sensors and electronic controls, they will have more confidence to move on to the real-world engineering systems.

In Year 2, students work on real-world systems with real constraints such as the washing machine which requires much deeper knowledge of electrical engineering. As mentioned previously, students will have to link knowledge from 3 different modules to re-engineer a home washing machine using their own subsystems. Instead of learning the topics in isolation, this project enables students to see the practical application of the different modules and how they are linked together. In future implementation, students will design and build the different subsystems that make up an electric vehicle (EV).

When it comes to Year 3, students are free to innovate and build projects that have the potential for commercialisation, that is, highly innovative and with complexities befitting the final year level. Students are free to choose the type of projects for this module; they are also supervised by lecturers who are teaching the supporting modules. When students encounter problems with modules or project, they can immediately seek help and work together with “experts” to solve their problem. Student motivation for learning the modules is high because the content is highly relevant to the project they are working on.

<table>
<thead>
<tr>
<th>Year</th>
<th>Module &amp; Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Analogue Electronics and Applications (AEA): Students work on an Arduino-based smart system using Lego, electronics, sensors and microcontroller programming to simulate smart real-world applications.</td>
</tr>
<tr>
<td>2</td>
<td>Power Electronics and Applications (PEA), Sensors and Instrumentation (SIN), and Microcontroller and Applications (MA): Students build sub-systems of a real washing machine linking these three modules.</td>
</tr>
<tr>
<td>3</td>
<td>Integrated Project (IP), Intelligent Motion Control (IMC), Applied Analogue Electronics (AAP), and Embedded Systems and Applications (ESA): Students anchor the PrBL work on the project module supported by the 3 remaining core modules.</td>
</tr>
</tbody>
</table>

The year 3 implementation best represents the full essence of PrBL. The projects carried out by the inaugural batch of 11 students in the project module, Integrated Project, are open-ended and unique; for example, an exercise coaching robot for seniors and a mobile phone application that assists drivers to locate their vehicles in car parks.

**Integrated Learning Space**

An innovative feature of the PrBL is the integrated learning space for the Engineering Product Development (EPD) option in Year 3. Lessons for the three project-supporting modules are conducted in one single laboratory location where the project is carried out. The timetabled hours for each supporting module and the project module are 3 and 11 respectively, with a combined total of twenty hours (3x3 + 11). As students
have sole access to the EPD laboratory, the learning of modules and developing of project becomes integrated; remark from a student on the EPD illustrates this, “Students are able to learn lots of new things and immediately implement in our project. Thus, we memorize all the concepts and also have a chance to use our knowledge in our own project after learning”.

Results and Observations

The survey results for the Year 1 PrBL experience were positive. Of the 163 students who responded, 85.9% agreed or strongly agreed that project work has helped them to stimulate their creative and innovative abilities; 79.8% responded that the project work has helped them in understanding the modules and overall learning experience while 76.1% have indicated that the project was interesting and it excites them about engineering. In addition, 85.9% of the students have also said that the project experience has allowed them to connect classroom’s instructions and real-world problem solving. These are all positive indicators to show that Year 1 students have found the PrBL experience useful for them and have motivated them to learn engineering. Students were open to learning through working on projects even though this was just an initial exposure for them.

The survey for Year 2 washing machine projects is consistent with results obtained for year 1. There were 129 Year 2 EE students who responded to the survey. Students indicated that they were positive about the Year 2 PrBL experience with 78.9% agreeing that this experience has helped connect classroom instructions with real-world problem solving. 82.7% of the students also felt that they have more understanding of the module which is higher by 2.9% compared to the Year 1 figure, 79.8%. The lower figure for Year 1 is possibly due to the fact that Arduino programming is not in the Year 1 syllabus and this is something “extra” that students learn in order to implement smart control of electronics; the additional learning is perceived as not directly related to the module.

(1) Real-world projects with constraints vs Creativity & Innovations

It is also noted that the Year 2 students were less positive in areas such as “the project allowing them to stimulate creative and innovative abilities” as the Year 1 had 85.6% agreement while Year 2 only have 77.3%. The results confirm some things about the PrBL implementations for Year 1 and 2 students. One key reason is that Year 1’s projects are simulated and scaled-down versions of real-world projects. This means that students can be more creative and innovative when proposing solutions. However in Year 2, the projects are real-world projects which have actual constrains, and this limits the type of solutions that Year 2 students can propose.

(2) Learning in a community

One key observation from the survey was the importance students placed on the interactions between students and lecturers for both year 1 and 2 – 87.7 % of Year 1 and 89.2 % of Year 2 students agree that it is a highlight of the PrBL experience. This underscores the vital importance of the community and social dimensions in learning. As it is well known, maintaining a positive classroom climate is a must before effective learning can take place. It is thus important too in any project-based activities, the social dimension must not be stifled; indeed, it should be built in to facilitate staff-student and student-student interactions. Future PrBL implementations may explore linking service learning to afford more opportunities for interactions at the same time help students relate engineering to society more meaningfully. This potent mix of pedagogies, PrBL and service learning, is promising in getting students to appreciate the relevance of engineering to society and at the same time allowing them to see how they can apply engineering for the benefits of society.

(3) Learning Space

The survey results showed that having a conducive workspace is important in facilitating project work. The difference in the learning space has an impact on how students perceive their learning experience.

Year 1 students had to work on their projects in regular classroom, which means the daily moving of components in boxes and equipment on trolley to the classroom and the mess created in the classroom may impacted the learning experience as the students indicated that planning was 77.3% compared to Year 2 students (83.2%). This can be due to the fact that Year 2 had better facilities in the laboratory where all project resources reside. This finding shows that the appropriate learning space can have an impact on students learning experience. For ideal PrBL implementation, proper project workspace is definitely more conducive than traditional laboratories, and hence should be a factor for consideration during the planning process.

(4) Challenging but fun learning

While both year 1 and 2 students are excited about engineering as a result of the PrBL projects, it is noted that Year 1 students seems to be more positive about the experience and had more “fun” as the overall rating for the PrBL experience was higher at 77.9% vs Year 2 students at 68.2%. This could be due to the lighter nature and variety of year 1 projects compared to the more challenging real-world project of year 2. Thus, it is indeed a challenge to design a PrBL project that is both fun and challenging that would continue to excite and motivate students while having them to learn content. It is hoped that future implementations will achieve more positive outcomes on both aspects by incorporating more interesting and diverse sensors for year 1 and adopting a
different project idea for year 2, for example, an electric vehicle.

(5) Facilitators & Facilitation

Facilitation plays a key role in deciding the outcomes of the PrBL (Arisoy & Stojcevski, 2009). A group of lecturers and technical service officers (TSOs) are involved in facilitating and supervising the project work. In the course of supervising the project work, both the lecturers and TSOs may either provide a lot of help or very little help at all; there are also the problem of facilitator doing too much for the learners. It is important for both the lecturers and TSOs who are involved to be in synchronization in carrying out the PrBL projects to yield positive learning outcomes.

Conclusions

From the Ngee Ann experience, it can be seen that the PrBL pedagogy is promising in transforming engineering education. By using projects as a driving question, students construct knowledge as they apply what they learn through study & research, discussion with facilitator and peers, self-reflection, and hands-on practical work that tests the understanding of theories. The Chinese philosopher, Xunxi, is right: “Not hearing is not as good as hearing, hearing is not as good as seeing, seeing is not as good as mentally knowing, mentally knowing is not as good as acting; true learning continues up to the point that action comes forth.”

References


**Annex 1**

**Table 2. Year 1 Survey Results**

<table>
<thead>
<tr>
<th>Questions (4-point Likert Scale)</th>
<th>% of combined Agreed &amp; Strongly Agreed</th>
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<tbody>
<tr>
<td>1) The C&amp;I Week widens my interactions with my course mates and lecturers.</td>
<td>87.7%</td>
</tr>
<tr>
<td>2) The C&amp;I Week helps me connect classroom’s instructions and real-world problem solving.</td>
<td>85.9%</td>
</tr>
<tr>
<td>3) The project work helps stimulate my creative and innovative abilities.</td>
<td>85.9%</td>
</tr>
<tr>
<td>4) I am now better able to observe, ideate, validate, design and present project with real world applications</td>
<td>83.4%</td>
</tr>
<tr>
<td>5) The time allocated is sufficient for me and my teammates to complete the project.</td>
<td>82.8%</td>
</tr>
<tr>
<td>6) The project work helps me in understanding of the learning module and overall learning experience.</td>
<td>79.8%</td>
</tr>
<tr>
<td>7) The project was interesting and it excites me about engineering.</td>
<td>76.1%</td>
</tr>
<tr>
<td>8) The mini video project capturing the learning journey during the C&amp;I Week haps me self-reflect my own learning.</td>
<td>73.6%</td>
</tr>
<tr>
<td>9) Overall, I enjoy and like the C&amp;I Week.</td>
<td>77.9%</td>
</tr>
<tr>
<td>10) Overall the programme is well planned and good.</td>
<td>77.3%</td>
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</table>

**Table 3. Year 2 Survey Results**

<table>
<thead>
<tr>
<th>Questions (4-point Likert Scale)</th>
<th>% of combined Agreed &amp; Strongly Agreed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) The C&amp;I Week widens my interactions with my course mates and lecturers.</td>
<td>89.2%</td>
</tr>
<tr>
<td>2) The C&amp;I Week helps me connect classroom’s instructions and real-world problem solving.</td>
<td>78.9%</td>
</tr>
<tr>
<td>3) The project work haps stimulate my creative and innovative abilities.</td>
<td>77.3%</td>
</tr>
<tr>
<td>4) I am now better able to observe, ideate, validate, design and present project with real world applications</td>
<td>76.8%</td>
</tr>
<tr>
<td>5) The time allocated is sufficient for me and my teammates to complete the project.</td>
<td>77.3%</td>
</tr>
<tr>
<td>6) The project work haps me in understanding of the learning module and overall learning experience.</td>
<td>82.7%</td>
</tr>
<tr>
<td>7) The project was interesting and it excites me about engineering.</td>
<td>75.1%</td>
</tr>
<tr>
<td>8) The mini video project capturing the learning journey during the C&amp;I Week haps me self-reflect my own learning.</td>
<td>78.3%</td>
</tr>
<tr>
<td>9) Overall, I enjoy and like the C&amp;I Week.</td>
<td>68.2%</td>
</tr>
<tr>
<td>10) Overall the programme is well planned and good.</td>
<td>83.2%</td>
</tr>
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</table>
ON POSITIVE EFFECTS OF DESCRIBING PROCEDURES OF DERIVING SOLUTION FOR PROBLEMS IN MATHEMATICS CLASS BY DIALOG-STYLE

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Abstract

My purpose in this paper is to introduce you to my method to improve students’ abilities to explain the other students for mathematical notions by writing the procedures for solving their problems tackled in class.

This method is based on the thought of “manabiai” advocated by Professor Nishikawa at Joetsu University of Education and is considered as one of active learning.

Especially I have been trying to introduce my students to not only knowledge of mathematics but also what students get through this class since my “manabiai” class started.

Keywords: cooperative learning, active learning, questionnaire, mathematical education, curriculum management

1. Introduction and Motivation

To begin with, I want to show you a typical example which one of my student in the first grade wrote as an answer for one simultaneous equation.

![Figure 1 Typical writing for answer](image)

We experience that a lot of students in our school write only formulae and hardly read between the formulae.

This sheet shows me that a lot of Japanese students would think we can only get an answer and the processes towards the solution are not necessary, we don’t write the courteous procedure if possible. On the other hand, we, mathematics teachers, know whether they can understand the problem and the necessities for mathematical tools, skills and notions. Moreover I wish they could acquire the talent of explaining them to the other person.

In this paper I try to substantiate that my practice for the last three years is more effective than one kind of active learning, that is, “manabiai” method. Here “manabiai” method was introduced in ISATE2016. Moreover I wish some participants will be interested in my practice and “manabiai” method, and I’d like to discuss improving this method in the near future.

Although I have practiced active learning by “manabiai” method to my classes since the latter half of the 2008 academic year. I have one trouble in regards to my practice. There are only a few students that couldn’t consult his/her classmates even if they couldn’t solve their problems on their own. I believe all students should have communication skills as well as mathematical notions and skills after they will graduate from their school and to work at their company. In my mathematics classes there are about three fourth of 90 minutes in each class for students to solve problems in their textbook which I give them.

First of all, we, math teachers, always think that how our students obtain mathematical skills and techniques and also seize how to consider various phenomenon in nature from the mathematical view.

Though I have been looking for ways of solving these concerns, I couldn’t get any solution.

By the way, in 2016 I came up with a certain thought.

That was to write down a solution as if you would explain your classmate to each other’s faces by gentle and understandable ways.

I continue to do this writing down procedure almost every time in every class during one year.
2. “Manabiai” as One Method of Active Learning

I briefly explain “manabiai” to whom it is not familiar. Because I perform this practice on the basis of “manabiai”, one of various methods in active learning.

“Manabiai” is thought as one method of cooperative and active learning. Professor Nishikawa at Joetsu University of Education advocated about twenty years ago and proclaims that “manabiai” is a thought consisted of three views of education: First, children have their excellent talents on their own. Second, teachers should prepare students’ learning environment to promote their learning. Moreover teaching ought to entrust students. Third, school is the place where students acknowledge that their fellows are indispensable to themselves for doing their own tasks or subjects in school activities.

Professor Nishikawa often says that there aren’t concrete ways in “manabiai”, so we may call all the classes based on these three views “manabiai” classes. So, “manabiai” class are not limited to specific subjects. Therefore we have possibility to expand almost all subjects in all types of schools, including high school, KOSEN, or university.

But I think that there is an orthodox method as “manabiai” or we, who practice “manabiai”, should keep some rules in class.

First, at the first time of all the classes in a year teachers have to illustrate why “manabiai” class will be needed for students.

Second, teachers should set up subjects or problems each time and estimate students’ activities in class, that is, they get musts which teachers indicate or aim to that day.

Third, teachers give students as much freedom and time as possible to solve problems of that day. For attaining this purpose they can leave their own seats and talk with their classmates about solutions. They do not always keep their seats.

Hence the better “manabiai” works, the better this practice is.

3. How to do this practice

Honestly I confess that there are some students who give up solving problems and that due to giving freedom to students in class some students are chatting with small talks.

Although I encourage them to be able to solve some problems and get mathematical notions, I can’t break their solid mind. But my main concern is that I have these students tackle problems providing in class and contemplate them as hard as possible.

Under these circumstances, I began with doing this practice.

First of all, I will explain this practice in detail.

This practice is done for almost 10 minutes before the end of the classes.

I give all the students in class the following sheet.

Each student writes the procedure towards a solution of their selected problem on their own as if they would explain it plainly to their classmates, who doesn’t know how to solve the problem. So this written form looks like scenario. Therefore I call this practice Dialog style writing.

And then each student selects one of all the problems they tackled in each class as they like.

Next they assume one “virtual” classmate who couldn’t understand or solve his/her selected problem until that time.

Concerning the selected problem, they describe the procedure as if they will explain it to their virtual friend and write that scene like a script or scenario.

I want to make them write the procedure of solving the problem as if they will explain how to solve the problem to their classmate politely and graciously. So by continuing this procedure a lot of times I think they could get mathematical notions and skills deeply than they solve the problems on their own.

4. As a Curriculum Management

The Ministry of Education, Culture, Sports, Science and technology (MEXT) says that the next Course of Study, which plans to start in 2020, includes Active Learning. MEXT defines Active Learning as the following in YOUGOSHU in 2012 (the original in Japanese) : Active Learning is not one-way teaching method like lecture, but a general form of teaching method by which learners can attend classes positively. Active Learning aims to raise the whole talents for learners to adjust, solve and tackle various kinds of problems occurring in our societies in the 21st century. (I paraphrased the original sentences.)

In various restrictions we all struggle to teach our own subjects, but main limitation is time. I think that teaching time is not assigned enough compared to their contents of each subject.

Therefore we must create some effective methods to attain our purpose of fostering engineers in our school.

As one solution, I propose to join mathematics and Japanese language together, in detail, to describe their procedure to solution by explaining their friends, who assume that they can’t solve the same problem. In particular, I even think that this friend needn’t to exist, that is, I allow this friend to be a virtual student. Because in our Japanese school there are some students, who aren’t good at communicating their classmates. So I come up with one idea. If these students are training to explain how to solve the problem to a virtual friend, they are finally to explain to real friends.

5. My practice for the last three years in Kisarazu College, NIT

I started this practice for two classes of the first grader and the second grader in the second term in 2016, and have been practicing until now.
I usually do this practice at the last 10 minutes of each class. So my students totally write down around 50 sheets through an academic year.

At the end of the academic year 2016 and 2017, I did questionnaires to each class. This questionnaire contains ten items, and one of ten items is concerning this “reflection sheets”. Here I will show you one student is developing his writing ability.

In general, the quantity of the writing at the beginning of April was little. Furthermore, the sentences were not dialog-style but monolog-style. It is only an explanation for a problem.

But the following sheet was written by one student on 25th June, 2018. I could interpret she deeply understand this problem and mathematical notions involved in this problem. For this class my students had experienced this practice around twenty times for almost two months. I am sure that this practice can enhance my students' mathematical talents and the skills of explaining some problems they would work out to their classmates.

Figure 2 This sheet written on 25th June, 2018

And I change “manabiai” class little by little every year by taking into account students’ questionnaires’ answers.

But the frame of this practice is almost the same in last three years.

In our school a period of time in one class is 90 minutes.

The procedure of my one class is the following

1) Doing mini test (10 minutes), which is concerning about the contents they have learned until the previous time,
2) Exchanging mini test side by side and marking it by students (about 5 minutes),
3) Explaining brief outline of the content on that day (from 10 to 15 minutes),
4) Students’ activity (about 60~70 minutes) to solve the problems on that day,
5) Comment students’ overall activities on that day to promote students’ activity next time (about a few minutes).

6. Analysis of questionnaires (1)

In this section I introduce students’ comments in questionnaires. I said this practice started in the latter term of the 2016 academic year. The 2016 and 2017 academic years were my trial ones for this practice. So I didn’t take decent questionnaires, only gathered their comments for this practice.

In 2016 my students of the third grade said the following.

1) Through this practice I could understand the problems deeply.
2) It is difficult to write the procedure of solution. So I need to understand the problem than ever.
3) By experiencing this practice I could explain real classmates.
4) I could have confidence in showing my classmates to explain our problems.
5) I acknowledged my extent of how deep I could understand our problems through this practice.

And so on.

I could congregate 40 comments in this class, and most of them are positive, although ten percent is negative. Some students, writing negative comments, said, “I don’t know why I must do this practice”.

Next my students of the first grade in 2017 said the following.

1) It is useful and effective for me to explain a virtual friend, who don’t solve a problem, how to solve it. Because this practice boost my achievement in maths.
2) At the beginning of this practice I hesitate to do it, but I think this practice will influence “manabiai”.
3) This practice is useful for the simulation as real conversation with my classmates when I consult about mathematical problems.
4) I can show the procedure of solving the problems to my classmates better than ever through this practice.
5) I can understand the contents in each class better than ever.

And so on.

I could collect 39 comments in this class, and almost all of them are positive, although about ten percent is negative. But these students, writing negative comments, din not completely deny this practice.
As above comments of my students, I confirmed this practice from the latter term in 2016 to 2017 would be useful and effective for my students.

7. Analysis of questionnaires (2)

I did the questionnaires on 4th June, 2018 to the second graders, to whom I have taught since last academic year, and on 5th June to the first graders respectively. So the second graders have been receiving this practice since last year.

My questionnaires consist of the following five questions:
1) Do you think you would get deep understanding for your problem picking up when you describe the procedures of solution by dialog-style?
   YES, NO, I CAN’T DETERMINE
2) Do you think you get ability of explaining to your friends for your problem picking up when you describe the procedures of solution by dialog-style?
   YES, NO, I CAN’T DETERMINE
3) Do you increase your opportunities for explaining your problem picking up when you describe the procedures of solution by dialog-style?
   YES, NO, I CAN’T DETERMINE
4) What is your reason to pick up your problem for explaining the procedures to your “Virtual” friend?
5) What do you think of this practice? Let me know your opinions.

At first I get the following result in Question1.

<table>
<thead>
<tr>
<th>Table 1 Question1 (people)</th>
<th>YES</th>
<th>NO</th>
<th>I Can’t Determine</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st graders</td>
<td>29</td>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td>2nd graders</td>
<td>29</td>
<td>2</td>
<td>8</td>
</tr>
</tbody>
</table>

This table shows that most of both graders think that this practice is helpful for deep understanding of the mathematical contents in class.

Next concerning Question2, I get the following result.

<table>
<thead>
<tr>
<th>Table 2 Question2 (people)</th>
<th>YES</th>
<th>NO</th>
<th>I Can’t Determine</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st graders</td>
<td>28</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>2nd graders</td>
<td>28</td>
<td>3</td>
<td>8</td>
</tr>
</tbody>
</table>

With regard to Question4, I could get various views for them to choose their problem picking up among several problems. So I arranged all comments and got the following three views;
(1) I chose the problem which I could solve on my own.
(2) I chose the problem which I consulted my friends about it when I had been tackling it.
(3) I chose the problem which I thought it was the most important among problems we worked out on that class.

<table>
<thead>
<tr>
<th>Table 3 Question3 (people)</th>
<th>YES</th>
<th>NO</th>
<th>I Can’t Determine</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st graders</td>
<td>15</td>
<td>20</td>
<td>7</td>
</tr>
<tr>
<td>2nd graders</td>
<td>8</td>
<td>23</td>
<td>8</td>
</tr>
</tbody>
</table>

With regard to Question5, I could get various opinions in relation to this practice as if they would explain the procedure of solving the problem to their “Virtual” friend.

Here I introduce some opinions.
[The first graders]
1) In case of explaining my friend, this practice is helpful for me. Moreover my friend says, “Your explanation is straightforward.”
2) I select more difficult one among problems given on that class. Because I must ask this problem for my friend to understand the procedures towards the solution. And once I understand it, I explain the other explanation to my virtual friend. So I think my mathematical thought would beef up.
3) I am not good at explaining to the other people. So it takes more time to get used to this practice.
4) I think it is difficult to explain what I understand and can solve the problem to my classmates.
5) I think throughout this practice I can explain various matters in order to the other people.

[The second graders]
1) By this practice, I think I can get how to solve the problems better compared to when I wouldn’t do this practice.
2) I sometimes noticed that I couldn’t understand the problems essentially by explaining it to the virtual friend.
3) Throughout this practice I can explain the procedure of the problem to real classmates when he/she asks me to it.
4) I believe this practice can pay off and I can get the ability of explaining something which I have to tell.
5) Throughout this practice I acknowledge several important points on that content in class.

Above these comments my practice of describing the procedure towards the solution is worthwhile and almost all of my students are for this practice.

8. Conclusions and Remarks

As a lot of my students evaluate this practice postively, I will continue and enhance this practice more effectively in the near future.

Especially my next aims are as follows.
1) By using ICT, I search for the possibility that this practice will be able to automatic. Especially all classmates can see the other classmates’ answer sheets for this practice and judge which one is best or which one is understandable for each student.
2) I want to evaluate students’ reflection sheets by somewhat unified criteria.
3) I also like to research on the relationship between this practice and mid-term/term exams.
4) If it can be possible, I want to substantiate this practice would be effective concerning communication skills in their workplace after they will graduate.

In conclusion, I believe this practice will help them utilize some advice of their classmates by solving quite a few problems in school and encourage them to communicate with their colleagues after they are to work in society.

But I think it is hard to prove the above phenomena. So I want to demonstrate this practice will be effective to create their communication skills and boost their mathematical talents throughout this practice.

Furthermore, I also improve this practice from a ICT point of view.

I also think “manabai”, one of active learning methods, will be a base of this practice. Because in “manabai” class all students help each other accomplish the subjects every time and then it is necessary to talk about the subjects each other and if some students are having trouble solving the problems the other classmates help them.

Nevertheless some Japanese students in our school can't depend on their classmates to solve the problems he/she faces difficulties, that is, they can't solve them. Therefore they must break their own barrier to settle the problems.

So I think this practice will be one method to break their communication barrier.

Finally I hope “manabai” will be becoming more familiar not only in Japan but also in the other countries and this practice will be proven effective in the near future.

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EXAMINING THE INTERPLAY OF INDIVIDUAL LEARNER DIFFERENCES AND ACHIEVEMENT IN L2 PRONUNCIATION THROUGH META-ANALYSIS

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Abstract

This paper offers a synthesis of the available studies on three areas in L2 Pronunciation Learning Strategies, that is, language-learning strategies, motivation, and the joint influence of motivational factors and learning strategies on the achievement of L2 pronunciation. By so doing, this study attempts to uncover the significant possibility of the mechanisms through which L2 learners regulate their individual learner differences, drawing upon the theoretical framework of self-regulated learning (SRL) (Oxford, 2017) recently investigated in L2 vocabulary learning by Zhang, Y., Lin, Zhang, D. & Choi (2017). SRL is defined as the notion in which “self-regulation of academic learning is a multidimensional construct, including cognitive, metacognitive, motivational, behavioral, and environmental process that learners can apply to enhance academic achievement” (Dörnyei, 2005, p. 191). The SRL framework in L2 pronunciation might reveal the mechanisms through which learners regulate their motivation and learning strategies, hoping to find out that practitioners and researchers alike develop pedagogical intervention, so that more learners could actively get involved in the class and, in consequence, achieve higher attainment in L2 pronunciation comprehensibility.

Keywords: individual learner differences (ILD), language learning strategy, L2 pronunciation (achievement), motivation, self-regulated learning (SRL)

Introduction

The interrelationships of critical factors involved in L2 pronunciation development have been attracting scholarly attention in the past few years (Oxford, 2017; Pawlak & Szyszka, 2018). Studies in L2 pronunciation to date have devoted to uncovering the effects of individual learner differences (ILD) on the L2 learning process with some investigating the role of motivation in the learning process (Nagle, 2018; Saito, Dewaele, & Hanzawa, 2017: Saito, Dewaele, Abe & In’nami, 2018) and others exploring learning strategies as a significant predictor of pronunciation performance (Baker-Smemoe & Haslam, 2013; Sardegna, Lee, & Kusey, 2017; Szyszka 2017; Veliz, 2015). In spite of considerable advances in our understanding of several factors in successful L2 pronunciation achievement, however, SLA in pronunciation in the last decade indicates that only scant attention was paid to the mediating role of ILD with the empirical evidence being scarce, patchy, and inconclusive. Thus, there is an urgent need for more studies in this field that would examine the role of ILD variables, as well as combination of the variables with respect to the efficacy of L2 pronunciation instruction.

This paper intends to overview this research gap in the literature, and offers a synthesis of the available studies on three areas in L2 pronunciation, that is, language-learning strategies, motivation, and the joint influence of motivational factors and learning strategies on the achievement of L2 pronunciation. By so doing, this study challenges the significant possibility that unveils the mechanisms through which L2 learners regulate their motivation and learning strategies, drawing upon the theoretical framework of self-regulated learning (SRL) (Oxford, 2017) recently investigated in L2 vocabulary learning by Zhang, Y., Lin, Zhang, D. & Choi (2017). SRL is defined as the notion in which “self-regulation of academic learning is a multidimensional construct, including cognitive, metacognitive, motivational, behavioral, and environmental process that learners can apply to enhance academic achievement” (Dörnyei, 2005, p. 191). The SRL framework in L2 pronunciation might reveal the mechanisms through which learners regulate their motivation and learning strategies, as Zhang et al (2017) suggests that “vocabulary learning is a proactive process that includes both a person is motivated to learn vocabulary, and an active and complex use of cognitive and metacognitive vocabulary-learning strategies” (p.68). In the following section is argued whether or not the integrated model probing the multidimensional construct is possible.

The Link between L2 Pronunciation Learning Strategies, Motivation and Achievement

Pronunciation Learning Strategies and Achievement: Pronunciation Learning Strategies (henceforth, PLS) is a term coined by Peterson (2000), whose pioneering work identified 43 tactics via self-reports in the form of diaries and interviews collected from 11 adult learners of Spanish across beginner, intermediate, and advanced
proficiency of learners. The 43 tactics were grouped into the 12 PLS, namely, representing sounds in memory, practicing naturalistically, formally practicing with sounds, analyzing the sound system, using proximal articulations, finding out about TL pronunciation, setting goals and objectives, planning for a language task, self-evaluating, using humor to lower anxiety, asking for help, and cooperating with peers.

Very few studies have quantitatively examined the extent to which the application of PLS in fact translates into greater achievement of L2 pronunciation. First, Eckstein (2007) aimed to investigate the correlation between PLS and spontaneous language performance, deploying the Strategic Pronunciation Learning Scale (SPLS). The data of 183 international students at low intermediate, intermediate, and high-intermediate levels of proficiency were measured with the SPLS, and a standardized speaking Level Achievement Test (LAT).

The analysis found that three PLS positively correlated with pronunciation performance, such as noticing pronunciation mistakes, adjusting facial muscles while speaking and asking for help with the pronunciation of new English words. In this line of research Berkil (2008) conducted a study in which he examined the PLS use and pronunciation attainment in the case of 40 Turkish university students representing different levels of proficiency. The quantitative analysis of the data, measured in terms of his Strategy Inventory for Learning Pronunciation (SILP) reading a passage and performing a free response task, revealed no significant correlation between overall PLS use and attainment, however, three of the strategies included in the SILP demonstrated statistically significant difference between participants at different proficiency levels, more specifically, the participants of moderate group showed more reliance on purposeful listening to sounds and listening to tapes television, movies or music.

In yet another attempt to look into the relationship between the frequency and duration of PLS use and pronunciation performance in semi-spontaneous speech in the case of 40 students of teacher education at a university in Chile, Véliz (2015) applied the SPLS and modified the instrument comprising 36 statements representing strategic devices and a 5-point likert-scale to scrutinize both the frequency and duration of PLS use. The attainment of pronunciation performance in semi-spontaneous speech was assessed by means of a test designed by the researcher, and evaluated by two raters. The research found no major correlation between the frequency and duration of PLS use and pronunciation performance, but yielded positive relationship in the case of the levels of pronunciation intelligibility. In a study involving 63 Polish university students majoring in English, Rokoszewska (2012) investigated the relationship between PLS use, and the perception and production of TL vowels, in which perception was assessed with three listening tasks, while production was evaluated through articulation tasks and reading minimal pairs and a continuous text. The analysis revealed a weak but significant correlation between PLS use and production of English vowels and diphthongs.

Also worth mentioning in this section is the project conducted by Szyszka (2017), who conducted a mixed-methods study among 94 trainee teachers of English as a foreign language at a Polish university, investigating the interplay between the use of PLS and different levels of language anxiety. The data were quantitatively and qualitatively collected, yielding several findings as follows: (1) compensation and memory PLS were employed more frequently by anxious trainee teachers, (2) higher input anxiety levels were connected with less frequent use of social PLS, (3) higher processing anxiety levels correlated with more frequent use of memory and compensation strategies, (4) higher output anxiety levels were accompanied by more frequent use of compensation PLS and less frequent affective strategies, and (5) anxious and non-anxious pronunciation learners differed significantly in their use of a number of pronunciation learning tactics (Pawlak & Szyszka, 2018, p. 311). Baker-Smemoe and Haslam (2013) is one of the few studies that examined in depths the effect of language learning aptitude (i.e., learners’ natural ability to learn languages) and learning contexts (i.e., EFL or ESL) on the PLS use and pronunciation achievement. Participants were recruited from two different contexts, EFL participants enrolled in two intensive English language schools in Beijing, China and ESL participants from intensive language institute at a major university in US. They were further divided into four groups of 15 to 16 participants each according to the Pimsleur Language Aptitude Battery (PLAB) Test, namely, EFL high aptitude, EFL low aptitude, ESL high aptitude, and ESL low aptitude, and completed pre-/post-pronunciation tests at the beginning and end of a 10-week speaking class. The Pronunciation scores in global foreign accent fluency, comprehensibility, and accuracy were compared with both overall and individual section PLAB scores and the PLS use. Results indicated that learning context plays a limited role in strategy use However, participants’ post-test pronunciation scores suggested that aptitude affects pronunciation accuracy and pronunciation strategies affect comprehensibility, indicating that strategy and aptitude impact different aspects of pronunciation.

Motivation and Achievement: While the use of PLS has some positive effect on the achievement, it seems unlikely that L2 learners demonstrate adept use of PLS unless they were motivated to learn. The longitudinal data of 26 English-speaking learners of Spanish were presented by Nagle (2018), who scrutinized L2 Spanish pronunciation development over a yearlong period and learners’ motivation change over the same period. The longitudinal data were collected via a simplified picture description task five times a year spanning their second, third, and fourth semesters, and rated by 18 native speakers of Spanish regarding comprehensibility and accentedness. A quantitative motivation survey based on the L2 Motivational Self System and an open-ended questionnaire on their language learning beliefs once per semester were completed by participants. Nagle (2018) mentioned that “Learners were consistently evaluated as very comprehensible despite the presence of a moderate foreign accent (p.33).”
suggested that although motivation decreased overtime, learners’ comprehensibility and accentedness improved during the research period. Similar line of inquiry was conducted by Saito et al. (2017), probing the predictive power of motivation for L2 speech learning at a university EFL classroom in Japan, where 40 first-year students attended over one academic semester. The development of L2 oral proficiency was investigated employing pre-/post pronunciation tests at the onset and end of a semester, and a motivation questionnaire which consists of five factors: Factor 1: Integrativeness, Factor 2: Instrumentality, Factor 3: Nativelikeness orientation, Factor 4: Lexicogrammatical orientation, and Factor 5: Comprehensibility for vague and long-term future. Although the comprehensibility of learners’ speech rated by five native speakers did not reach statistical significance at a $p < .05$ level, the achievement in comprehensibility was significantly related to Factor 5 in the motivation profile, e.g. I want to study English because better English proficiency is crucial for my future job., and marginally to Factor 4, e.g. Appropriate and rich vocabulary. Following this, Saito et al. (2018) took an exploratory approach towards investigating “the triangular relationship between L2 motivation/emotion, use and L2 speech (p. 25)” of 108 high school EFL learners. The learners completed (1) motivation/emotion questionnaire provided at the beginning of the research programme and (2) oral proficiency data collected at the beginning and the end of the period, rated by 5 native speakers of English. The cross-sectional and longitudinal analyses by Saito et al (2018) found the significant role of motivation towards attaining L2 comprehensible speech in the classroom. However, this line of discussion, i.e., the immediate impact of motivation on L2 attainment, was questioned by an inquiry of educational psychology (Horino & Ichikawa, 1997, p.24). According to a recent survey of language learning strategy by Rose, Briggs, Sergio, & Ivanova-Slavianskaia (2017), the role of strategy has caught scholarly attention as a mediator of motivation, and the other their L2 English vocabulary learning strategies, together with a vocabulary test. According to the researcher, “The model was a good fit for the data in this study, if compared to the saturated model, with $X^2(3) = 1.722$ ($p > .05$), $CFI = 1.000$, and $RMSEA = .000$ with a 90% confidence interval of 0.000 to 0.132). Both IM ($\beta = 1.09$) and EM ($\beta = 0.69$, $p < .001$) loaded significantly on the latent variable of motivation, and both metacognitive ($\beta = 0.95$) and affective strategies ($\beta = 0.92$, $p < .001$) loaded significantly on the latent variable of vocabulary-learning strategies (Zhang, Y. et al, 2017, p. 63, 64).” They suggested that vocabulary learning strategies mediate the relationship between motivation and vocabulary knowledge, as shown in the Figure below.

**Figure.** Structural model of the relationship between motivation (MOT), vocabulary-learning strategies (STR), and vocabulary knowledge (VK). (Zhang et al, 2017, p.65)

**Conclusions**

The mainstream research of PLS in the last decades has showcased the continuation of language learning strategies in SLA, examining to what extent the application of PLS translates into greater achievement of L2 pronunciation (Eckstein, 2007; Berkil, 2008; Rokoszewska, 2012; Véliz, 2015). The other group has probed the effect of ILD variables or combination of variables, for instance, language learning aptitude, anxiety, and motivation on the PLS use and L2
pronunciation achievement (Baker-Smemoe & Haslam, 2013; Nagle, 2018; Szyszka, 2017). Based on the limited number of studies reviewed in this article, it is impossible to argue which one is particularly more promising than the other, however, the third group integrating SEM as conducted by Sardegna et al (2017) in L2 pronunciation and Zhang et al (2017) in L2 vocabulary could be forged in this direction. It is hoped that the findings will help practitioners and researchers alike develop pedagogical intervention, so that more learners could actively get involved in the classroom and thus achieve higher attainment in L2 pronunciation comprehensibility.

Acknowledgements

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References


AN ATTEMPT TO USE A PHYSICS EXPERIMENT CONDUCTED BY A FIFTH-GRADE KOSEN STUDENT FOR LOWER-GRADE STUDENTS BY EMPLOYING LEARNING MATERIALS ON ELECTRONIC DEVICES

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Abstract

In order to become an engineer who has scientific analytical skills, gaining knowledge about physics is crucial for lower-grade Kosen students during their five-year curriculum as physics is the foundation for studying engineering subjects. However, it may be difficult for these students to understand the usefulness of their future businesses while studying. In advance, we are engaged in using the contents of the higher-grade engineering course for lower-grade physics in order to combine liberal arts subjects and specialized subjects and enrich career education. In this study, we examine learning materials on electronic devices, which were used in an experiment on gravitational acceleration conducted by a fifth-grade student.

The learning material was developed by several fourth- and fifth-grade students as a graduation-research task. The material can detect a falling object by employing semiconductor lasers and photo-integrated-circuit diodes in vacuum and recording the number of seconds taken by the object to fall, by using a microcomputer (Arduino Mega 2560 Rev. 3). In experiment training, a fifth-grade student demonstrated the material to 214 first-grade students and asked them to analyse the gravitational acceleration as per the seconds recorded by the microcomputer. Some simple questionnaires were completed before and after the training.

There were two important reasons for the first-grade students to attend the experiment training. First, the lecturer was a fifth-grade student, and the learning material was handmade. Many of the first-grade students had an affinity with the fifth-grade student and thought positively about learning advanced techniques in higher grades. Second, an understanding of gravitational acceleration is crucial. It appeared that the first-grade students had little quantitative understanding of the concept as 90% of them answered that the acceleration of a falling iron ball was greater than that of gravity (9.8 m/s2) in the air. However, it was found that the training promoted qualitative as well as quantitative understanding.

In conclusion, a physical science experiment was performed for lower-grade students by employing learning materials on electronic devices by a fifth-grade student. This attempt effectively integrated liberal arts subjects with specialized subjects.

Keywords: Physics, specialized subjects, cooperation between subjects, teaching by a student, learning material, electronic device, teaching effort

Introduction

There are 3.4 million Japanese students who graduate from junior high school [International Standard Classification of Education (ISCED)-11 level 2]. A total of 3.30 million students (97%) go on to high school (ISCED-11 level 4) for three years and 0.05 million (1.5%) go on to the National Institute of Technology (Kosen) (ISCED-11 level 3 and 5-6) for five years. Among those who graduate from high school, 2.56 million (78%) attend university or college (ISCED-11 level 5-8). Since 73% of high school students follow general courses of study, where the ratio of literary and science subjects are comparable, it follows that 1.87 million junior high school students (57%) only begin to study specialized subjects in university or college. On the other hand, the Kosen curriculum, which includes engineering courses that range from high school to first-year college level, offers five years of specialized subjects. Therefore, Kosen students are a minority group that studies specialized subjects from an early age. These future engineers study science, mathematics, and other specialized subjects to acquire knowledge about natural science and data analysis. The early study of such subjects has both benefits and drawbacks due to individual differences for strength of intentionality to engineer in admission to Kosen. On the one hand, Kosen students can begin their engineering education early and acquire wider knowledge and skills, which benefits students with strong directionality. However, students with weak directionality lose motivation to study in the
initial stage. Therefore, it is important that Kosen students improve their career consciousness in addition to their study of science and mathematical subjects. For lower-grade Kosen students, gaining knowledge about physics is crucial, as physics is the foundation for studying engineering subjects. However, it may be difficult for these students to understand the usefulness of their future businesses. Furthermore, physics is difficult for them because they are not used to mathematical description of physical laws and principles. In advance, we use the content of the higher-grade engineering course for lower-grade physics in order to combine liberal arts subjects with specialized subjects and enrich career education. In this study we examine learning materials on electronic devices, which were used in an experiment on gravitational acceleration conducted by a fifth-grade student. This study provides useful insight into collaboration between universities and high schools.

Materials and Methods

The physics experiment materials included free fall equipment in a vacuum. It was developed by several fourth- and fifth-grade students as a graduation research task. The knowledge and skills for making the equipment are tied to the department to which the graduation research students belong (Department of Electronic Control Engineering). Since the curriculum of the Department of Electronic Control Engineering includes complex electrical and electronic engineering, computer science, and mechanical engineering (“Mechatronics”), it can be said that this equipment controlled by a microcomputer and sensors embodies the department. Figure 1 shows an image of the equipment. The equipment detects a falling object by employing semiconductor lasers (output power of 1 mW and emission wavelength of 650 nm) and photo-integrated-circuit (IC) diodes (Hamamatsu Photonic S7183) in a vacuum made by a rotary pump and an acrylic pipe and recording the number of milliseconds it takes for the object to fall by using a microcomputer (Arduino Mega 2560 Rev. 3). The acrylic pipe is 1 m long due to improvement of portability. The semiconductor lasers and the photo-IC diodes are arranged in a pair in increments of 150 mm on the pipe. The fall of objects is controlled by an electromagnet and solid-state relay module. An execution program is written by Arduino IDE (Version 1.8.3) for the microcomputer. The microcomputer is connected to a laptop computer (Operating system: Windows 10) with Universal Serial Bus 2.0. The microcomputer and drive parts of the electromagnet are in an aluminium container. The equipment sits on a carriage and can be transported by hand. The power supply for the equipment can be drawn from a classroom outlet.

The experiment and training was composed of: (1) a questionnaire before the experiment, (2) introduction of the lecturer (a graduation research student), (3) experiment and analysis of gravitational acceleration and (4) a questionnaire after the experiment. The questionnaires before and after the experiment asked about gravitational acceleration and attempted to ascertain the educational effect of this training. Figure 2 shows a typical scene from the experiment. In the experiment first-grade students observed a steel cap and a wrap film with a small steel washer that fell simultaneously from the top of the acrylic pipe both in a vacuum and in the air. The steel cap was only used to measure falling time for the gravitational acceleration. Table 1 displays data on the distance of the steel cap and its falling time. In this table, the theoretical value is also shown for reference. The measured times were several tens of ms longer than the theoretical ones. This difference of time is thought to be due to the magnetization of the steel cap. In fact, the falling time was within 1 ms compared to the theoretical value after 150 mm. Therefore, gravitational acceleration g was analyzed by the difference in fall time t from 150 mm to 900 mm and then substituted the time with the following
mathematical formula, \( y = \frac{1}{2} gt^2 \). Here, \( y \) is distance. Finally, the arithmetical mean gravitational acceleration was calculated. The first-grade students were divided into groups of nine or 10 and watched a demonstration by the lecturer. During the demonstration, the lecturer let the first-grade students perform the operation (rotation of vacuum valve and pressing a button to turn off the energization of the electromagnet, and so on) as much as possible. After the demonstration, the first-grade students drew a diagram of coordinate versus time characteristics on grid paper. Then they calculated the average gravitational acceleration and compared it with the theoretical value.

The graduation research student (lecturer) carried this equipment into the classroom and lectured to first-grade students (5 classes, 214 people total) during 90-minute physics classes. Classroom teachers helped facilitate.

**Results and Discussion**

Figure 3 shows results of the questionnaire before the experiment training. In response to the question, “Which iron ball and wing dropped from the same height falls quickly in vacuum?”, 98% of the first-grade students understood that they fell at the same time. However, in response to the question, “Is the acceleration of iron ball falling in the air larger or smaller than the gravitational acceleration 9.8 m/s²?”, up to 53% of the first-grade students answered “small.” Of course, this answer is incorrect because the iron ball decelerates due to air resistance. The correct answer is “same” (any objects have the same gravitational acceleration), and the ratio was only 9.6%. Although air resistance exceeds range of the first year, it was thought that qualitative and quantitative understanding about free fall does not combine well and that allied force was not nurtured.

Figure 4 provides results of the questionnaire after the experiment training. In response to the question, “Did you understand the structure of experiment equipment and the principle of measuring time?”, 87% of the first-grade students answered yes. Thus, the first-grade students could see that they can fabricate hand-made devices using technical knowledge and skills such as mechatronics and make them useful in upper grades. In addition, in response to the question, “Was the lecturer's explanation easy to understand?”, 94% of the first-grade students answered yes. The graduation research student, who is a senior student, helped the first-grade students tackle the experiment training with a feeling of familiarity and got them interested in the experiment equipment. It seems that it was good to have a part that spoke his school life and course after graduation as a self-introduction of the graduate student.

<table>
<thead>
<tr>
<th>Time (theoretical) (s)</th>
<th>0</th>
<th>0.1749</th>
<th>0.2473</th>
<th>0.3029</th>
<th>0.3498</th>
<th>0.3911</th>
<th>0.4284</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time (sample 1) (s)</td>
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<td>0.250</td>
<td>0.307</td>
<td>0.354</td>
<td>0.397</td>
<td>0.435</td>
</tr>
<tr>
<td>Time (sample 2) (s)</td>
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<td>0.335</td>
<td>0.382</td>
<td>0.424</td>
<td>0.463</td>
</tr>
<tr>
<td>Time (sample 3) (s)</td>
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<td>0.260</td>
<td>0.319</td>
<td>0.373</td>
<td>0.409</td>
<td>0.448</td>
</tr>
<tr>
<td>Time (sample 4) (s)</td>
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<td>0.263</td>
<td>0.320</td>
<td>0.366</td>
<td>0.408</td>
<td>0.448</td>
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<tr>
<td>Time (sample 5) (s)</td>
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<td>0.252</td>
<td>0.309</td>
<td>0.357</td>
<td>0.399</td>
<td>0.436</td>
</tr>
<tr>
<td>Time (sample 6) (s)</td>
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<td>0.297</td>
<td>0.354</td>
<td>0.401</td>
<td>0.443</td>
<td>0.481</td>
</tr>
</tbody>
</table>

Table 1. A data of distance of the steel cap and its falling time.

![Fig. 3. A result of questionnaire before the experiment training. (1) Which iron ball and wing dropped from the same height falls quickly in vacuum?, and (2) Is the acceleration of iron ball falling in the air larger or smaller than the gravitational acceleration 9.8 m/s²?](image)

![Fig. 4. A result of questionnaire after the experiment training. (1) Did you understand the structure of experiment equipment and the principle of measuring time?, and (2) Was the lecturer's explanation easy to understand?](image)
himself in the first half of the experiment training class. Using free-fall equipment, the graduate student conducted the experiment with the first-grade students and obtained two educational effects: a deeper understanding of gravitational acceleration among young students, and improvement of motivation for the study of specialized subjects in upper grades.

Conclusions

In this study, we conducted an experiment about gravitational acceleration for first grade students using free-fall equipment. The first grade students deepend their understanding of gravitational acceleration and strengthened their motivation to study specialized subjects in the upper grades. Since motivation for learning improves career consciousness, it can be said that they are essential components to help students select their occupations. We think that improvement of academic achievement and of career consciousness is like knitting; the students choose their desired occupations because the two factors are braided together. While orienting toward such a philosophy, we will continue to increase opportunities that combine liberal arts subjects and specialized subjects.

Acknowledgements

The authors would like to thank Mr. Takahiro Tanaka who was the lecturer for this experiment training.

References


Abstract

The advancement of the internet has enabled the rapid developments of massive open online courses (MOOCs) in education. MOOCs allow a new form of student-centred learning where learners can interact with the course materials at a place, time and pace convenient to them. In MOOC platforms, every action of the learners including learning progress, assessment results, and interactions with the course facilitator and peer learners are all recorded providing comprehensive data on learning behaviour, which can be used to improve the learning materials, as well as to enhance the learning experience of the learners. This pilot study focuses on the development of a mini-version of MOOC on mathematics for Higher Diploma students in the Engineering Discipline of Hong Kong Institute of Vocational Education. The mini-MOOC is designed as a pre-class self-learning tool with the following two objectives: 1) to refresh and to strengthen the mathematical foundations of the students before embarking on the study of the module of engineering mathematics; and 2) to provide information to the teachers on the students’ mathematics competencies so that the teachers can make necessary adjustments to their teaching before the classes. The mini-MOOC covers common types of mathematics functions in engineering applications including linear, quadratic, polynomial, exponential, trigonometric forms, etc. It provides a quick revision on their properties followed with tests to refresh and reinforce their understanding, and then followed by examples showing their applications in solving engineering problems, so as to arouse the students’ interest and preparing them to pursue further in their study of the module. At the same time, the results of the tests provide information to the teachers on the students’ mathematic competencies. In this paper, the development of the mini-MOOC is discussed and the use of pre-tests and post-tests for measurement of student learning is also explored.

Keywords: Massive Open Online Courses, MOOC, online education, engineering education, vocational education, mathematics, Hong Kong.
Diploma is five HKDSE subjects at Level 2 or above, including English Language and Chinese Language. As Mathematics is a necessary skill in engineering, most Higher Diploma programmes offered by the Engineering Discipline require Mathematics be included in the five HKDSE subjects. The mini-MOOC is designed as a pre-class self-learning tool with the following two objectives: 1) to refresh and to strengthen the mathematic foundations of the students before embarking on the study of the module of engineering mathematics; and 2) to provide information to the teachers on the students’ mathematics competencies so that the teachers can make necessary adjustments to their teaching before the classes.

The mini-MOOC covers common types of mathematics functions in engineering applications including linear, quadratic, polynomial, exponential, logarithmic, and trigonometrical functions. It provides a quick revision on their important properties to refresh and reinforce their understanding. Examples showing their applications in solving engineering problems are illustrated, so as to arouse the students’ interest and prepare them to pursue further in their study of the module. A short test is introduced after each sub-topic to test the students’ understanding. At the same time, the results of the tests provide information to the teachers on the students’ mathematic competencies. In this paper, the development of the mini-MOOC is discussed and the use of pre-tests and post-tests for measurement of student learning is also explored.

**Literature Review**

MOOCs seem to become a new fashion in the context of Technology Enhanced Learning. MOOCs allow a new form of student-centered learning and are becoming a widely-discussed new phenomenon in education such as the models of staff/student and student/student interactions (Martin, 2012). Furthermore, actions of learners and interactions can all be recorded for quality assurance related to the current online education practices in tracking and supporting personalized feedback (Jung, 2011).

There are significant areas of opportunity related to the evaluation of MOOCs, however standards regarding their pedagogical quality have yet to be agreed upon. Bernal et al. (2013) recommend that MOOCs should apply the same quality standards used in formal open and distance courses. In assessing the educational quality of distance education and open learning resources, researchers generally used indicators related to pedagogical, functional and technological factors. For Barbera, Gros, and Kirschner (2012), time is a critical factor that has also been used as a quality measure, since it is related to the amount and the sequence in which people learn through the accumulation of experiences. In collaborative learning environments, the implementation of strategies that promote participants’ self-regulation is recommended (Franco-Casamitjana, Barbera, & Romero, 2013).

Daniel (2012) suggests that MOOCs could be evaluated by learners and educators, with the aim of producing league tables that rank courses. He suggests that poorly performing courses would either disappear due to lack of demand, or would undertake efforts to improve quality. Another route forward is to equate quality with participation measures (Dillenbourg et al., 2013). The primary focus would be on assessments of the learning outcomes of individual participants, thereby placing the learner at the center of measures of quality. This is in keeping with the growing focus in the research on developing multiple measures of learner behavior, motivations and engagement, through the employment of various learning and data analytic techniques. Since MOOCs shift agency towards the learner, there is a need to foreground learner perspectives, using various measures of learner perceptions, behaviors and actions, and experiences as the foundation for assessing quality.

Furthermore, the idea of KPIs can also be applied to evaluate the success rate of a MOOC. In some cases, the Kirkpatrick (1976) model was adopted as an appropriate approach to the evaluation of training in organizations consisting four levels of training outcomes: reaction, learning, behavior, and results (Bates, 2004). Reaction was originally used to describe how much participants liked a particular training program and the term evolves along with time to assess trainees’ affective responses to the quality (e.g., satisfaction with instructor) or the relevance of training (e.g., work-related utility). Learning measures are quantifiable indicators of the learning that has taken place during the course of the training typologies. Behavior outcomes address either the extent to which knowledge and skills gained in training are applied on the job or result in exceptional job-related performance. Results are intended to provide some measure of the impact that training has had on broader organizational goals and objectives.

**MOOC Development in Vocational Training Council**

Development of MOOCs is one of the current initiatives of the Vocational Training Council (VTC). Around ten MOOCs were developed across multiple disciplines (http://mooc.vtc.edu.hk). The Department of Construction plays a leading role in developing MOOCs in VTC. In the field of construction, the MOOCs developed by the Department include “Unauthorised Building Works”, “Principles of Measurement” and “Building Pathology-Aluminium Window Inspection”. The MOOCs are not only open to current students and alumni, but also to staff for continual professional development.

This MOOC project is built on the successful applications of the previous MOOCs developed by the Department of Construction. The “Unauthorised Building Works” (UBWs) MOOC addressed the common phenomena in Hong Kong, which created serious safety and health hazards to occupants and public such as the collapse of tenement block at 45J Ma Tau Wai Road in 2010, and Fa Yuen Street fire in 2011. Such
UBW-related accidents claimed many lives and injuries in the past. The MOOC aimed to enable learners to grasp the legal meaning of UBWs by going through the Buildings Ordinance and Minor Works Control System, and to explore common UBWs in Hong Kong and their impacts on building structures. The “Principles of Measurement” MOOC provided basic understanding about the important role of Quantity Surveyor in many infrastructures such as Mass Transit Railway, Express Rail Link, and tall buildings in Hong Kong. The aims of the MOOC were to equip learners with essential knowledge of quantity surveying practice in building measurement, get them familiar with the measurements in reference to the Hong Kong Standard Method of Measurement of Building Works Fourth Edition (HKSMM4), to explain the importance of industry-wide used uniform and standard method for measuring the quantities of materials in building works, to realize the numerous means of measuring techniques, and to illustrate the working procedure.

More MOOCs are under development in all eight disciplines in VTC, namely Engineering Discipline, Applied Science Discipline, Business Administration Discipline, Childcare, Elderly and Community Services Discipline, Design Discipline, Hotel, Service and Tourism Studies Discipline, Information Technology Discipline, and International Cuisine / Chinese Cuisine Discipline. At the time of this submission, the MOOC described in this paper is being developed under the initiative for the Engineering Discipline. These MOOCs will be launched in Academic Year 2018/19, which starts in September 2018.

All the MOOCs in VTC are developed using edX, which is an MOOC provider founded by Harvard University and Massachusetts Institute of Technology in 2012. It hosts online university-level courses in a wide range of disciplines to learners around the globe. EdX is a non-profit organization and runs on the free open edX open-source software platform. While the platform is open source, these MOOCs can be free-of-charge or charged, at the discretion of the course developers. In 2017, edX has approximately 1,800 courses and has 14 million users worldwide (Shah, 2018). EdX also conducts research into learning behaviours based on how learners use its platform.

MOOC Platform

VTC adopts dual platforms for the MOOC development, as shown in Figure 1. The development platform is for the course developers, whereas the production platform is for the users or the learners. The course developers create the MOOC in the development platform. The available functions in the platform include uploading learning videos, adding multi-language transcripts, creating discussion forum among peer learners, and setting up quizzes and grade books. All the trial runs are done in the development platform. The development platform is further subdivided into two sites – the studio site and the browsing site. In the studio site is to where the course developers do the uploading and updating. After the updates, the developers can see the outcomes of the MOOC in the browsing site.

Once the MOOC production is completed and obtained approval from the internal quality assurance process, the MOOC on the development platform is then copied to the production platform for the users. The copying function is not real-time and only activated by the Centre for Learning and Teaching (CLT), which serves as a quality assurance agent and a gate-keeper for the MOOC development.

The production platform is for the learners and daily operations by the developers. Similar to the development platform, the production platform also entails the studio site and the browsing site. The studio is for the developers for the final checking on the course contents and daily operations of the MOOCs. The browsing site is the final output for all VTC learners, where they logon and access to the course contents.

MOOC Design

The outline of the mini-MOOC for the engineering mathematics and the nominal time for completing the tasks are given in Table 1. The mini-MOOC begins with an introduction video. There are then six learning videos in the mini-MOOC. Each of those learning videos lasts just 3 minutes, such that the duration is well within the attention span of the learners.

<table>
<thead>
<tr>
<th>No</th>
<th>Learning Task</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Introduction video</td>
<td>2 mins</td>
</tr>
<tr>
<td>2</td>
<td>Pre-test</td>
<td>30 mins</td>
</tr>
<tr>
<td>3</td>
<td>Video 1: Key concepts in functions</td>
<td>3 mins</td>
</tr>
<tr>
<td>4</td>
<td>Post-test 1</td>
<td>5 mins</td>
</tr>
<tr>
<td>5</td>
<td>Video 2: Linear functions</td>
<td>3 mins</td>
</tr>
<tr>
<td>6</td>
<td>Post-test 2</td>
<td>5 mins</td>
</tr>
<tr>
<td>7</td>
<td>Video 3: Quadratic functions</td>
<td>3 mins</td>
</tr>
<tr>
<td>8</td>
<td>Post-test 3</td>
<td>5 mins</td>
</tr>
<tr>
<td>9</td>
<td>Video 4: Polynomial functions</td>
<td>3 mins</td>
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<tr>
<td>10</td>
<td>Post-test 4</td>
<td>5 mins</td>
</tr>
<tr>
<td>11</td>
<td>Video 5: Exponential functions</td>
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</tr>
<tr>
<td>12</td>
<td>Post-test 5</td>
<td>5 mins</td>
</tr>
<tr>
<td>13</td>
<td>Video 6: Trigonometric functions</td>
<td>3 mins</td>
</tr>
<tr>
<td>14</td>
<td>Post-test 6</td>
<td>5 mins</td>
</tr>
<tr>
<td>15</td>
<td>Student satisfaction survey</td>
<td>5 mins</td>
</tr>
</tbody>
</table>

Figure 1 MOOC Platforms in VTC (CLT, 2018)
In the introduction video, the course facilitator also the first author welcomes the learners and set the scene for the MOOC learning. Figure 2 gives the screen capture of the opening of the introduction video, which gives the objectives and outline of the mini-MOOC. A refreshing background in green with random mathematical expressions is chosen to help setting the scene for the subsequent learning.

![Figure 2 Introduction video of the mini-MOOC](image)

A pre-test and post-test approach, which is well accepted method for measuring effects in education intervention, is adopted in this mini-MOOC design. One pre-test and six post-tests are used to measure the degree of change occurring as a result of the MOOC learning.

The pre-test has around 60 multiple-choice questions, which covers all the scope of all six post-tests. In other words, the post-tests are subsets of the pre-test test. The pre-test is essential to benchmark the different mathematical competencies of the individual Higher Diploma students before MOOC learning. In the pre-test, the questions are direct without the need of complex calculations, the learners are expected to finish the test within 30 minutes.

As shown in Table 1, the pre-test is placed right after the introduction video. After each learning video for a sub-topic such as linear functions, the learners must complete the post-test for that sub-topic. With the similar difficulty to the pre-test questions, each of the six post-tests has around ten multiple-choice questions. The learners are expected to finish it within five minutes. The rationale of using six post-tests instead of using one post-test at the end of the MOOC is that this approach allows a more accurate measurement of the effectiveness of individual learning videos by minimizing the time between watching the video and the completion of the test. In addition, the approach allows greater flexibility for the learners, who can watch one learning video and do the corresponding post-test within ten minutes and start another set at their convenience.

The results of the pre-test and the post-tests provide useful information to the teachers on the students’ mathematical competencies and the analysis of the effectiveness of the mini-MOOC for the projective objectives. The results will be available after the implementation of the mini-MOOC by end of 2018.

At the end of the mini-MOOC, a student satisfaction survey is provided to gather feedback about the user experience of the mini-MOOC. The information is important in quality assurance and future development.

**MOOC Administration**

While this pilot study aims to develop the mini-MOOC on mathematics eventually to all Higher Diploma students in the Engineering Discipline of IVE, the mini-MOOC will be open to the students in phases. In the production stage, the mini-MOOC is first tested by trial runs by sample staff who have experience in teaching engineering mathematic modules in Higher Diploma curriculums. Once the mini-MOOC is enhanced with the feedback from the sample staff, it will be ready for the Higher Diploma students. The release of the mini-MOOC will be in three stages. In the first stage, the mini-MOOC will be released to the students studying Higher Diploma in Civil Engineering, who are expected to have a stronger mathematical background. As the mini-MOOC is designed as a pre-class self-learning tool, it will be made available for the students in the first month of the Academic Year 2018/19. The first semester of the Academic Year starts in September 2018, around 200 civil engineering students will take the first mathematic module called “Engineering Mathematics”. The pre-test results are first collected once the students joined the mini-MOOC. The pre-test can provide information to the teachers on the students’ mathematics competencies so that the teachers can make necessary adjustments to their teaching before the classes.

In the second stage, the mini-MOOC will then be released to the students studying other Higher Diploma programmes in the Department of Construction. In the final stage, it will be released to all Higher Diploma programmes in the Engineering Discipline. The experience in the MOOC developed will be shared to VTC staff through sharing sessions.

**Conclusions**

A mini-MOOC for foundation mathematics is developed for Higher Diploma engineering students in Hong Kong under the MOOC development initiative in VTC. The successful application of the mini-MOOC will generate valuable information and experience, which not only help students’ active learning in MOOC platforms, but also are important milestones for further development of more advanced topics in engineering mathematics.

**References**


TEACHING AND LEARNING TOOLS FOR THE EDUCATION IN MECHANICAL ENGINEERING

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Abstract

The present work addresses the question of the evolution of teaching contents for the mechanical engineering students (Bachelor and Master degrees) by developing an active learning, learner-centered approach, which is based on the use of smart and digitalized academic tools. The Mechanical Engineering Department of the Lille University develops in this context an ambitious project since several years, it consists in the creation of new digital resources and on the development of a technological platform. Several aspects related to our pedagogical approach are discussed in this paper, we propose a method which shows how, step by step, it's possible to transform the classical university in a digitalized one, without losing its essence - our approach is essentially based on meaningful and collaborative learning, case studies or problem solving and critical thinking. To test the proposed approach several pedagogical experiments were conducted on different groups of students, the main idea being to test the feasibility of implementing these concepts (and to link them) in as many as possible classical courses such the materials science, mechanical manufacturing, eco-design, etc. A non-conventional approach (based on the PBL methods) was used, it also deals with organizational learning. The first objective of the paper is to describe the elements guiding the instructional design that contributed to the improvement of students' performance and attitude in training and learning; the second objective of the paper is to illustrate and discuss significant future challenges permitting to other educators to learn and adapt their teaching resources from our experience.

Keywords: active learning, training, learning, digital resources, learner-centered education, engineering.

Introduction

A very important number of authors underlined, during the last decades, the need for changes in pedagogical approaches, especially in engineering science. Among the more promoted solutions the active learning occupies an important place. On the other side, the campuses are considered as small cities with both residential/academic areas, where the development of sustainable environments to study, work and live are enhanced through the use of digital technologies and big/open data. An actual challenge of universities is thus to enhance the learning experience of students by providing them smart and digitalized academic tools.

In order to propose to the students of the Mechanical Engineering department of our University new attractive and useful resources for training and learning, several digital resources were recently developed, the followed idea being to give free elements to teachers and trainers, who can directly re-use them in their presentations or for their teaching supports. The provided courses can also be used for self-training, given that the provided media are composed of videos, self-assessment tools and/or practical case studies (which were designed and realised by involving the students).

The digital resources were then used and tested with success in several courses, at the Bachelor level, at the Mechanical Engineering department of the Lille University. The proposed approach is essentially based on collaborative and meaningful learning, case studies or problem solving and critical thinking development. The active learning was introduced also to provide opportunities for learners to think critically about the course content, through a range of activities that help them to prepare themselves for the challenges of professional situations involving problem solving. The start point was given by observations such those formulated by Huba and Freed (2000) who underlined that those that are learning the most in a classroom are the professors; the professors reserved for themselves conditions promoting learning: actively seeking new information, organizing it in a meaningful way, and having the chance to explain it to others. In this situation, the usual lecture format for most of the courses presents many challenges to both teaching and learning. Even if a traditional lecture allows an efficient presentation for a large body of content to a large number of students, this "one-way transmission of knowledge" often faces superficial learning and do not stimulate the students' motivation. The principal consequence is that a part of the students do not possess important skills for their future integration in the professional life. It is then necessary to find new forms of instruction, by placing the students in the centre of
the approach, in order to allow them to become independent and critical thinkers.

The Mechanical Engineering Department of the Lille University developed the P2NT-GM project (active pedagogy based on digital media and new technologies in mechanical engineering) which consists in the creation of new digital courses and on the construction of a technological innovative platform.

In this paper is presented one of the three digital courses realized between 2011 and 2014 in the framework of the previously cited project. The question of the evolution of the pedagogical content is equally addressed, given that these evolutions aim to propose good quality case studies or courses for the concerned students. Several aspects related to our approach are illustrated by presenting some pedagogical experiments conducted in this period with a group of students.

An educational approach based on active learning and the use of digital resources

Active Learning based pedagogical approaches. Active Learning is actually defined as anything that students can do to learn and train themselves except taking notes and passive listening of an instructor's lecture. Numerous research works proved that such approach helps students improving understanding and retention of information and can be very effective in developing higher order cognitive skills (e.g. critical thinking). However, restructuring a course by using elements of active learning can sometimes seem overwhelming for a faculty, with extensive time commitments in other realms and little or no formal training in pedagogy. In addition, adapting the content and the structure of a teaching resource with respect to the actual standards and regulations or by adapting the treated case studies and the lectures' content with respect to the industrial requests (and reality) are tasks which complicate a lot the preparation work and which request a huge time for the research dedicated to recovering correct and useful information to be used in the teaching activities (especially lectures and demonstrative works). The next section presents the active learning approach developed at the Mechanical Engineering department of the Lille 1 University.

The P2NT-GMP educational project

Context and usefulness. Several reasons pushed the teaching team of the Mechanical Engineering department of the Lille University to develop the P2NT-GM project, which is centered on an active pedagogy. We recall here as examples: the students motivation and attitude, the miss of time and specific tools (for trainers) dedicated to the development of digital resources. Given these reasons and the willingness of the team to help students in improving the success of their education and learning, it was decided to act on two distinct plans: on one side, create an innovative technological platform (financed mostly with our own resources) and on the other side realize new training and learning digital resources by taking advantage of the technical and financial support provided by two French foundations working in the engineering respectively the environmental fields. Note however that the development of these resources is not sufficient to improve the quality and the content of our lectures and resources, this is why it was equally decided to capitalize and to valorise our experience by increasing the number of exchanges with our educational, industrial and institutional partners, in order to get the best feedback possible which can be used for a continuous improvement of our practices and tools.

The main objective of the project is to favour the students' success by the mean of using digital media and by letting them instruct themselves in working environments such the technological platform that we developed. The learning is mainly based on an inductive method (tutored project) which consists in performing continuously the work by using case studies. This help the development of the technical skills of the students, contributes to the development of their criticism, conceptualisation, and to the improvement of their adaptability. A second objective of the project was to help educators developing and using the technical or digital means previously cited, in our establishment or in those that are our partners.

The technical platform. Our department develops since many years a platform dedicated to innovative technical equipments. In this framework the University financed the acquisition of innovative technical equipments and devices such the 3D measurement device and scanner, some fab lab equipments and 3D printers, industrial vision cameras and devices, foundry furnace or computer numeric control machines. Note that a big majority of these equipments are in free access for students several times a week, in order to let them practice and improve by individual working.

The digital resources. Linking the technical and digital resources (existing ones or to develop in the future) is on the other hand an excellent mean helping in improving the students' success and which allow them to train themselves thanks to the use of pedagogical resources with high level of educational interactivity. We naturally decided then to take advantage of the opportunities provided by the support offered by two foundations (digital universities) and we participated to several call proposals. Three of the proposed projects were approved, this offered to us the opportunity to put in practice our ideas and to develop new digital courses. The design of one of these digital resources will be presented in the next section.

The French digital universities UNIT and UVED. The development and the promotion of active-learning pedagogy is facilitated and supported in France since many years by the 7 digital universities working under the guardianship of the French Ministry of Education. Two of these digital Universities develop activities in the environmental and engineering fields: the digital University of Engineering and Technology (UNIT) respectively the Digital University of the Environment and Sustainability (UVED). These foundations provide support for faculty committed for implementing active-learning strategies in their courses by proposing training
opportunities and by furnishing example teaching resources and materials readily available.

Objectives. The availability of digital courses and the training for the use of innovative tools are factors strongly contributing to the development of autonomy of students in the acquisition of knowledge. The educational level of interactivity of the created resources must be strong; we decided then to realise resources of expository type, with an important use of communication tools with the learner (forum, chat, etc) and a strong presence of exercises, multiple choice questionnaires, case studies and other activities centred especially on the problem based apprenticeship or similar to the serious game activities. Our choice focused then on realizing numerical courses of the form of educational grains designed by addressing several fields of engineering sciences.

The realisation method. The project based approach and the problem based methods (see Barret and Moore, 2011) are inductive unusual methodologies of learning. It was decided to arrange the realised tools and to construct them under the form of educational grains grouped in two categories:
- sequential (the information is detailed in one grain)
- parallel: under the form of worksheets associated to elements giving the "theoretical" information attached to the methodology and the practical information declining its application to the case study.

The grains are imbricate and more other theoretical or practical tools were added: links to other courses, videos, examples of results, etc. The scope is to provide a set of resources conceived under the form of toolboxes or libraries. These boxes are opened by the learner one by one to learn, to self-evaluate or to acquire new knowledge and information. The more he will advance the more he will enter in the methodology details in order to find the right tool or information. The interest of the proposed structure is the fact that the searched information will be find very quickly. The teacher's role and contribution are essentially situated at the case study level and in the project approach. He will help the learner to address the good questions, will encourage him in opening one or another box, to make new researches. The main goal is to bring the learner to an important autonomy level, to help him in the acquirement of the method, and to push him in developing criticism with respect to the collected data or to the obtained results.

The projects' structure. The project is therefore inscribed in an active learning pedagogy and it is divided in three axis. The first one consists in purchasing of new technical innovative means, completed by the realisation of user guides and/or technical worksheets allowing to the learner to self-train. The second action concerns the development of new digital courses and educational kits allowing to other trainers to adapt the proposed media with respect to their needs and practices. Finally, the valuation and the capitalization of the acquired experience and of the developed tools are done by the redaction of a "feedback guide" and by presenting the developed approach at several events: congresses, symposiums, (e.g. Gruescu, 2014 and Gruescu et al., 2014).

Target audience. The digital resources we developed have for target students of licence level (L1, L2, L3) or master (M1, M2). The content was adapted with respect to the public and indications are given to learners in order to guide them to use the information associated to their competences and knowledge. Initial, continuing and apprenticeship training as well can be trained by using the realised resources, since the trainers have in possession an educational kit.

The 3PM - EFAU project for the UNIT digital university

We describe here the development and the implementation of an instructional design that focused on bringing multiple forms of active-learning and learner-centered pedagogies into a traditionally lecture-based introductory engineering course dedicated to mechanical manufacturing. The restructuring of this course was decided by several perceived deficiencies which are common to traditional lecture-based introductory courses. The most important concerns were the poor students' involvement and attitude, feelings that were shared by several faculty involved in the course presentation. Both written or numeric responses on course evaluations indicated in the past that students were not satisfied with it and they did not recognized equally the usefulness of the content to their education and future needs in professional work. Note that even if the students qualified that the lectures and the course materials were boring, they recognized however being more concerned with their test scores than with gaining a thorough understanding of the course material. Poor student attitudes were equally reflected by limited participation in class, poor attendance and almost inexistent individual instructor–student interactions.

Course description and study design. The course restructuring we describe here pertains to the lecture and tutorial classes of a two-semester course that typically enrolls annually around 100 students. The course was taught in a standard lecture format in the previous years and redesigned to emphasize active learning and student-centered pedagogy. It proposes a set of activities that aim a progressive simulation of the learner, which is close to industrial reality and thanks to which the learner will acquire and improve his/her technological skills. He will especially be able to know the different production processes, their characteristics and application fields. He will equally use his knowhow to define a production process and to integrate in the production analysis the quality, cost and delay constraints, in order to improve the productivity.

This digital resource (http://www.analyse-fabrication.univ-lille1.fr/co/001 MOG_web.html) is positioned as an application field of the organisation and methods department in a production workshop. Structured in 4 main parts, it is composed of theoretical presentations, videos, exercises and multiple choice questionnaires. It concerns students from higher and vocational education in initial or continuous training.
Any other vocational training can equally be done with the help of this tool. Finally the Master students or engineering students can use it for quick upgrading of their knowledge. Concerning the teaching public this module concern all kind of categories developing their activities in mechanical engineering field. Since it was conceived under the form of educational grains, it can be exploited in totality or partially. Project activities can also be proposed to students on the basis of this module, since the self-evaluation is possible thanks to the solved case studies or to the divers applications proposed under the exercise forms at the end of each chapter. We finally emphasize the remarkable work which was done in order to complete the resource with videos of high technical quality and which were realized based on realistic screenwriting.

The improvements in the course redesign. The first point to emphasize in the redesign of the course is the reorder of the course content. The presentation of the course was reordered in four main chapters and enriched in order to teach specific content within the context of broad conceptual themes. For example, a new lecture dedicated to the materials used for the machining tools production was integrated, it was designed to serve as an intellectual bridge between materials science and machining by chip removing. The active learning and the group problem solving were introduced in several lectures. Students work now organized in small groups, each case study needs several minutes of discussion in order to correctly state the addressed problem. During this period, the instructor would move from group to group in the classroom to monitor student progress and offer suggestions to the groups that are encountering difficulties. Note equally that we adopted several additional strategies to create a more learner-centered learning environment. Every lecture includes a set of learning goals made explicit to students in the lecture PowerPoint slides. The exam are labelled with the corresponding learning goals, in order to emphasize the alignment with assessment. A set of vocabulary terms was also included in the resource to help the students focus on important concepts. As part of the course revision, and based by the use of a moodle platform, we modified the assessment plan to include weekly quizzes. It was also choose to focus on using problem-based learning because these activities tend to be more succinct and less open-ended than the case-based studies; the interest of this approach is also to present the theoretical methodology by using real examples, contrary to many trainings which just present a specific tutorial. The general idea is to give free elements to teachers and trainers, who can directly re-use them in their presentations or teachings supports. It can also be appropriated by self-learning.

It must be finally emphasized that the digital resource that we developed is not only a classical course for students in universities, but also a free-access numerical resource which can be used by everybody in a professional context or for self-training. This resource has been used with a certain success in several departments similar to ours, in the partners' Universities.

Discussion and training experiments

Discussion about the 3PM-EFAU digital resource. A traditional lecture format in a large classroom presents several disadvantages, as was already emphasized previously. There is reason to believe that this deficit diminishes learning outcomes and may contribute to the loss of some of our most talented students, especially at the introductory level. The primary goal of the courses restructuring was to improve student attitudes, motivated by the hypothesis that this would lead to improved learning outcomes. It was then observed that incorporating active-learning and learner-centered pedagogy into the instructional design of our educational approach also lead to increased student attitude and performance. The courses redesign had another unanticipated benefit: it improved not only the students’ attitude toward the course but also the professor’s enthusiasm and implication. Machining by chip removing has been for a long time a problematic course for our department because of the deficiencies such superficial learning, poor student attitudes or suboptimal performance. As a consequence, educators or instructors often loosed enthusiasm for teaching this course after a few years. It is actually obvious that the interactive pedagogy (based on active learning) and the positive student reactions made this a much more exciting and rewarding course to teach. The changes we implemented also have had an impact at the departmental level. Based in part on the positive student reactions to interactive and student-centered pedagogy in the mechanical engineering courses, other colleagues seriously thing about implementing the use of digital resources in their courses. Since the same author taught the course before and after redesigning, the main outcomes of the new approach are that student attitudes and performance increased in response to the instructional design that we implemented.

Pedagogical and training experiments. We realised some experiments in our department which were used as case studies in the numerical courses that we developed for the French digital universities. We recall that the 3PM-EFAU course proposes an academic presentation of the mechanical manufacturing, and is based on the use of case studies. The general idea was to use a non-conventional approach which is in any way the one which will be discovered in the companies and in the organisations by the students or the auditors as soon as they will start their professional careers. This method is called the Problem-based Learning (PBL) and is described in many works (e.g. Barret and Moore, 2011). This pedagogical method is more interesting for students and auditors because it directly deals with real cases. Besides, the student is no longer a “listener” but becomes an actor of the methodology, which permits him to acquire knowledge and abilities more quickly and more durably. This method also deals with “organisational learning” given the proposed interactions between the working groups and given the time constraints that each team has to face. The students trained in the bachelor’s degree dedicated to mechanical engineering are formed to acquire technical, scientific
and organisational skills required by companies. Within the company, in their future professional life, they will be in charge of improving the products performances: energy consumption, optimal recycling, etc. by seeking innovative and optimised solutions. The tutored-project and all the chapters (e.g. the one related to materials-science) are realized by integrating the "learning by doing" concept (see Gruescu, 2014). The main outcome of this project is that, in addition to the increased interest of the students for the proposed approach, the acquired experience was used for the development of the so called ECO-PEM and ACVBat projects for the UVED University.

The institutional context. The redesigned or newly introduced courses that we implemented in the framework of active learning required significant time investment and consequent financial support. Given the encountered problems it worth capitalizing and valorising the acquired experience and the realized digital resources in order to allow to other colleagues to benefit of our advances and to use at our turn their eventual feedback. Attendance at national and international workshops or symposia, can naturally provide significant background theory and training. It was also possible to organize some regional meetings with colleagues form other universities, these occasions were as well opportunities to improve our practices and experience. These symposiums were particularly useful in providing the opportunity to discuss specific details of course redesign with individuals highly experienced in implementing active-learning and student-centered pedagogical approaches.

Indicators of the objectives’ achievement and capitalization

It was established to evaluate in a continuous way the achievement of the proposed objectives (short and mean term) from both quantity and quality points of view. This will permit to adjust and to propose some new actions if necessary. The measurement of the realization process was and will be done by using classical project management tools; concerning the results indicators, we favoured the satisfaction rate of the target audience and the capacity of the tools and engaged means to respond to their needs. An important parameter in this context was the resources’ use rate, which can be evaluated by using classical means such the accounting of the connexions number, etc. The main tools permitting to transfer our expertise and recommendations are respectively the educational kit (package) and the feedback guide. The latter can be continuously updated by organizing regularly meetings with partners from universities (initial, continuous or apprenticeship training) in order to share the experience related to the use of the digital resources or technical materials in already finalized or to come projects.

Conclusions

Active learning is a key aspect of the education, it can be applied to any learning environment from online to standard lectures or as a blend of these. The Mechanical Engineering department of the Lille University works since several years in implementing this approach in its educational system. The creation of a technological platform dedicated to innovative technical equipments and the reorganisation of existing courses (or the introduction of new ones) are the main initiatives to be emphasized in this context. The new digital resources were realized with the support of the French digital Universities, this allowed the reorganization of some courses by using active learning and by centring the education process on students. A good feedback and more positive results in students evaluation illustrate how changing the instructional design of a course, without wholesale changes to course content, can lead to improved student attitudes and performance. With respect to the use of the Problem-Based Learning methodology in the development of the resources it was shown that this approach permits in all the cases to train the learners, the results in terms of the appropriation of the subject being better than those which could have been obtained using conventional pedagogical methods.

In summary, we developed and implemented an instructional design that focused on incorporating active-learning and student-centered pedagogy in courses which were previously traditional lecture-based teaching activities. These changes led to sustainable improvements in student attitudes and performance. The course reorganization we described provides not only a model for revision of an individual course but can also be a catalyst for institutional reforms. Note finally that the force of this project lies not only in the interest of the treated themes but equally in its regional and national recognition.

Even if our approach has been applied to technological courses, it is clear that the application field is not at all limited. The second objective of our work was equally attained, the shared expertise and experience permitted to other educators to learn and to adapt their teaching resources and pedagogic approach by learning from our experience.

Acknowledgements

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HOW DO WE MAKE STUDENTS LEARN ENGINEERING? THE IMPORTANCE OF ORGANIZATION OF CLASSES BY CAPACITY ACCORDING TO THE CHARACTERISTICS OF STUDENTS

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Abstract

Nowadays, Japanese population, especially children who is below 15 years old, is decreasing. This has two meanings. One is that many educational institutions has difficulties to collect the students. Another meaning is that KOSEN has to accept the students who are not very interesting about engineering. In particular, some students enter KOSEN without sufficient knowledge for mathematics or physics to learn engineering. Therefore, in every year, there are students who have difficulties learning in college and have to repeat a school year or drop out. Moreover, each student in one class have very big gap of learning skills, teachers often have difficulties to teach.

We consider that one of reason about these problems are organization of classes for mathematics and physics. In our KOSEN, organization of classes of mathematics and physics place for just each specialized course, is not considering the characteristics of students. However, it is too difficult to identify each ability in all students. So, in order to discuss the importance of organization of classes by capacity according to the characteristics of students clearly and quantitatively, we analyse correlations of students' score of between each liberal arts subject in lower graders in our college.

As this analysis, we find that students have the higher score of the logical writing in Japanese and English, the higher score correlation between the subjects of several mathematics subject. These mathematics subjects need abilities of theoretical and logical thinking rather than the other one. This result is two meanings. The one is that their logical writing skill relate to mathematics strongly. Another one is that if their mathematical subjects' scores are low, it is thought that it is relatively easy to cultivate their mathematical abilities. In order to cultivate their knowledge for mathematics or physics to learn engineering, we will need to organize classes focusing on the structure of mathematical expressions.

Keywords: Organization of classes, Liberal Arts Education, Mathematics & Physics Education

Introduction

KOSEN is one kind of technical college in Japan, thus junior high school student who want to learn in KOSEN was very interested in Mathematics and Physics. However, in present days, KOSEN has to accept various student, including students who are not very interested in mathematics and physics because we have to maintain admission quota. Out KOSEN has four courses in one department (Industrial Systems Engineering); Mechanical system design course (hereafter M-course), Electrical and computer engineering course (E-course), Material and Bio engineering course (C-course), Civil Engineering and Architectural design course (Z-Course). However, student who insufficient knowledge for mathematics or physics to learn engineering enters any course. This fact brings some serious problems. The biggest one is “polarized academic performance”. Figure 1 shows that score of a midterm exam about physics in a course in our college (average score is 68 points). A Histogram is not shown gaussian distribution but also almost flat in all score range. This is an evidence for “polarized academic performance” we think. We also found that the tendency is shown in mathematics too.

![Figure 1. The Histogram of scores of a midterm exam about physics in a course in our college. The horizontal axis and vertical axis correspond to score distribution and number of students, respectively.](image-url)
“Polarized academic performance” brings several difficulties both of teachers and students. Who should the teacher target and teach? – If we teach for high-performing student, many low-performing students cannot understand. If we teach for average-scored student, many students feel boring about class because they are not majority.

We consider the difficulties of classes are caused by organization of classes in physics and mathematics.

In our KOSEN, organization of classes of mathematics and physics place for just each specialized course, is not considering the characteristics of students, thus we do not consider that how do students obtain their knowledges about physics, mathematics and engineering when we organized the classes.

Therefore, we discuss the importance of organization of classes by capacity according to the characteristics of students clearly and quantitatively, we analyse correlations of students’ score of between each liberal arts subject in lower graders in our college.

**Samples and analysing methods**

In order to discuss how do students obtain the knowledge about physics and mathematics, we choose performance of 3rd-graders of 2017 academic year as the sample. The main reason is that in the case of Japanese KOSEN, students finish most fundamental subjects up to the 3rd grade including physics and mathematics. Another reason is that we have their scores of National Achievement Test. Their scores more decrease than that of 3rd-graders of 2016 academic year. In particular, average of low-performing student decreases (Figure 2). From this result, we consider that this is not only we cease "doping" for National Achievement Test (Niwa & Nakamura, 2017), but also because of the diversification of the way that students acquire knowledge each course.

In analysis, we classify the fundamental subjects (Physics, Mathematics, Japanese, and English) that the student has taken for each related subject and calculate the average score of each fundamental subject. Based on
these average scores, we draw correlation diagram between mathematics and physics each course at first. In the next step, we calculate correlation coefficient of scores between all fundamental subjects to investigate the knowledge-based relationships between all subjects.

### Results

Figure 3–6 show correlation diagrams between score of physics and that of mathematics each course in our college. Score correlation between mathematics and physics of M-course (correlation coefficient; CC = 0.90) and E-course (CC = 0.84) are very strong. However, C-course (CC = 0.73) value indicates the weakest correlation. CC value of Z-course is just in the middle. On the other hand, in the C-course, the score range was the smallest in both mathematics and physics, in contrast, the score range of M-course was the biggest in both mathematics and physics. Table 1–4 show correlation coefficient table between all fundamental subjects. In these table, correlation coefficient larger than 0.7 highlight as yellow and it larger than 0.8 highlights as red, respectively. In table 1, we show results of M-course. M-course has the largest number of yellow and red highlights. Mathematics 1 and physics 1 (M1-P1) and 2 English subjects (EG1-EG2 and EG2-EC1) show the strongest relationships. English and physics have also strong relationships too. Table 2 shows results of E-course. From table 2, we find the connection between subjects in some mathematics subjects and physics exercise are the strongest. EG1-EG2 and EG2-EC1 have also strong relationships we find. Table 3 shows results of C-course. This table has only 4 yellow highlights which indicate that score range was the smallest in both mathematics and physics in spite of the knowledge-based connection between subjects are very weak. In table 4, we show results of Z-course. Table 4 has 2 red highlights and 4 yellow highlights. This is just in the middle between E-course and C-course. We summarized results in table 1–4 as table 5.

### Table 1. Score correlation coefficient between all fundamental subjects in 3rd grade of M-course. The first letter of the heading indicates the abbreviation of the subject name (M, P, J, and E are corresponding to Mathematics, Physics, Japanese and English, respectively), and in the case where there is the second letter, the item’s details are shown (E, G, W, C are corresponding to Exercise, Grammar, Writing, Conversation).

<table>
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<th>M2</th>
<th>M3</th>
<th>ME</th>
<th>PE</th>
<th>JG</th>
<th>JW</th>
<th>EG1</th>
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### Table 2. Score correlation coefficient between all fundamental subjects in 3rd grade of E-course. For more details of headings are same as Table 2.

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### Table 3. Score correlation coefficient between all fundamental subjects in 3rd grade of C-course. For more details of headings are same as Table 2.

<table>
<thead>
<tr>
<th>Course</th>
<th>M2</th>
<th>M3</th>
<th>ME</th>
<th>PE</th>
<th>JG</th>
<th>JW</th>
<th>EG1</th>
<th>EG2</th>
<th>EC1</th>
<th>EC2</th>
<th>P1</th>
<th>P2</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC</td>
<td>0.62</td>
<td>0.36</td>
<td>0.76</td>
<td>0.48</td>
<td>0.14</td>
<td>0.30</td>
<td>0.58</td>
<td>0.62</td>
<td>0.57</td>
<td>0.55</td>
<td>0.69</td>
<td>0.62</td>
</tr>
<tr>
<td>CC</td>
<td>0.27</td>
<td>0.76</td>
<td>0.41</td>
<td>0.50</td>
<td>0.46</td>
<td>0.70</td>
<td>0.55</td>
<td>0.46</td>
<td>0.58</td>
<td>0.54</td>
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</tr>
<tr>
<td>CC</td>
<td>0.28</td>
<td>0.00</td>
<td>0.02</td>
<td>0.01</td>
<td>0.21</td>
<td>0.14</td>
<td>0.34</td>
<td>0.30</td>
<td>0.22</td>
<td>0.14</td>
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</table>

### Discussion

From figure 3–6, table 1–4, and table 5, we find interesting tendency; if correlation coefficient between mathematics and physics leading from table 3–6 is large, then total number of yellow and red highlights in table 1–4 has large numbers. To explain about this tendency, we generate hypothesis about “memorize”.

### Table 5. Correlation coefficient between score of physics and that of mathematics each course

<table>
<thead>
<tr>
<th>Course</th>
<th>M</th>
<th>E</th>
<th>C</th>
<th>Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correlation coefficient</td>
<td>0.90</td>
<td>0.84</td>
<td>0.73</td>
<td>0.79</td>
</tr>
<tr>
<td># of subjects CC &gt;=0.7</td>
<td>14</td>
<td>10</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td># of subjects CC &gt;=0.8</td>
<td>3</td>
<td>4</td>
<td>0</td>
<td>2</td>
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</tbody>
</table>
When many students have to memorize something, they memorize about it related to something else. We consider that the results in case of M-course and E-course shows it. Because many subjects indicate strong relationship seen in Table 1 and 2. On the other hand, although students in C-course has narrow score range, and average score is high, results of C-course do not show it like M and E-course. We consider that this indicates differences about memorize-style. If student has strong relationships between score of mathematics and physics, they show that they can memorize various things in association. In contrast, students with low correlation between mathematical and physical scores may not have memory association and they may just remember it as a simple task. We define that this memorizing type is “scanner-type memorize”. In order to explain differences of memorize-style, we need to characterize of each course. Student belongs to M or E-course are required to utilize sophisticated mathematics usually. However, C-course students are not requiring it well. Because they are required to memorize chemical terms and biological terminology rather than utilizing mathematics. We are not planning on superiority or inferiority of the two memory styles. However, if a student has a scanner type memory style, it may be disadvantageous in logical thinking. At least, if student has “scanner-type memorize”, then class organization for fundamental subjects especially mathematics and physics needs to consider memorize-style for each student.

In order to verify the hypothesis on memory from another aspect, we investigate relationships between logical writing in Japanese and other subjects. We reclassify the students not by course but by sorting in logical writing in Japanese and extracting the top 40 and bottom 40 people at first. In second step, we recalculate correlation coefficient between all subject based on new classification (Table 6 and 7). From these results, we obtain a new finding. Although it is not as obvious as the result by each course, it is found that the top 40 have a strong correlation between mathematics. On the other hand, in case of the bottom 40, we find strong correlations in physics subjects. Naturally logical thinking is necessary also in physics. But admitting bringing textbooks to the examination may have influenced the results in case of physics. At least, in order to cultivate students’ logical thinking, we find logical writing is very effective. Kada and Niwa (2016) also pointed out that it is very effective to increase the interest in mathematics and physics by giving students a task that scientific thinking power is required during the classes of the Japanese.

As we have mentioned above, in order to organize of class for fundamental subjects especially mathematics and physics, it is not appropriate to simply classify by mathematical and physical scores. Naturally, it is not appropriate to classify by each course too. For appropriate class organization, we need to classify based on memorize-type each student including score of logical writing and English.
Conclusion

In this paper, we discussed about knowledge-based relation in fundamental subjects. Our conclusion as follows:

- In order to discuss how do students obtain the knowledge about physics and mathematics, we draw correlation diagram between mathematics and physics each course at first. In the next step, we calculate correlation coefficient of scores between all fundamental subjects to investigate the knowledge-based relationships between all subjects.

- Score correlation between mathematics and physics of M-course (correlation coefficient; CC = 0.90) and E-course (CC = 0.84) are very strong. However, C-course (CC = 0.73) value indicates the weakest correlation.

- We consider that this indicates differences about memorize-style. If student has strong relationships between score of mathematics and physics, they show that they can memorize various things in association. In contrast, students with low correlation between mathematical and physical scores may not have memory association and they may just remember it as a simple task. We define that this memorizing type is “scanner-type memorize”. If a student has a scanner type memory style, it may be disadvantageous in logical thinking. At least, if student has “scanner-type memorize”, then class organization for fundamental subjects especially mathematics and physics needs to consider memorize-style for each student.

- In order to verify the hypothesis on memory from another aspect, we investigate relationships between logical writing in Japanese and other subjects. As this result, although it is not as obvious as the result by each course, it is found that the top 40 have a strong correlation between mathematics.

- In order to organize of class for fundamental subjects especially mathematics and physics, it is not appropriate to simply classify by mathematical and physical scores. Naturally, it is not appropriate to classify by each course too. For appropriate class organization, we need to classify based on memorize-type each student including score of logical writing and English.

References
APPLICATION OF PROJECT-BASED LEARNING TO SMART BUILDING ENGINEERING EDUCATION – A CASE SHARING

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Abstract

Hong Kong government determines to transform this vibrant city into a world class smart city. Among the six major areas under promotion, “Smart Living”, “Smart Environment” and “Smart People” are highly related to smart building engineering education. This drift reinforces the current pressing task of educators, i.e. to nurture young talents to have the 21st century competencies and multidisciplinary knowledge and skills in order to cope with the complex problem of designing and maintaining intelligent, healthy and sustainable buildings for the smart city.

As a member of the Vocational Training Council (VTC), Hong Kong Institute of Vocational Education (IVE) is the leading vocational and professional education and training (VPET) provider committed to nurturing professionals for the development of the city. The curriculum of IVE engineering programmes requires every student to complete an industry-based student project (IBSP), in which he or she integrates and applies the learnt knowledge to tackle a practical problem encountered in an authentic workplace.

To align with the government’s policy on pursuing smart city development, IVE (Sha Tin) adopts project based learning (PBL) in the IBSP module within the scope of smart building engineering education. PBL is an innovative approach designed to engage students with different backgrounds in the investigation of a real-world problem. By using PBL, lecturers facilitate students through engineering design processes while students drive their own learning through sustained enquiries and team-based cooperation. PBL helps to strengthen students’ conceptual knowledge, build up their problem-solving abilities, and develop a positive attitude towards learning.

A total of six students studying in the final year of higher diploma programmes in computer engineering (CE) or building services engineering (BSE) were engaged in the same PBL-adopted IBSP which targets to create an automatically controllable, highly energy efficient and sustainable living environment inside buildings. Three lecturers having expertise in smart energy management, sustainable built environment and cutting-edge IoT applications respectively jointly supervised these six students. The synergy of the CE and BSE programmes was fully unleashed.

This paper reports the work of the students’ PBL-adopted IBSP, shares the challenges of implementing PBL in the teaching of smart building engineering. The assessment rubrics of the PBL-adopted IBSP are discussed. The student feedback taken at the end of their study is also analysed.

Keywords: Pedagogies in VPET, project-based learning, smart building engineering, smart city, multidisciplinary collaborations.

Introduction

VTC is committed to nurturing talents for developing Hong Kong. In the 21st century, educational practices that solely emphasize theoretical concepts are no longer sufficient. It is now more crucial for engineering students to learn how to become practical engineers. Practising to apply theoretical principles is the best done when real problems and hands-on activities are given in “projects”. For this reason, every IVE engineering student is needed to have exposure to projects about real-world problems which are usually mixed with complexity and uncertainty. Upon the end of their engineering studies, they should be able to identify the roots of the problem, encounter the difficulties, deal with the project constraints, and work out a feasible solution with creative design thinking skills and a positive learning attitude. PBL is a suggested VPET approach to guide engineering students to become work-ready engineers. In alignment with the recent policy of Hong Kong government on developing the city to be a world class smart city, six students studying in the final year of CE or BSE HD programmes were jointly guided by three lecturers with different expertise to conduct a PBL-adopted project on creating a smart, energy efficient and sustainable living environment in buildings. This paper shares the experience of applying PBL in the teaching of smart building engineering. Challenges of implementing PBL in the curricula of IVE engineering programmes and the assessment rubrics associated with PBL are discussed. The students’ outcome on developing smart city features based on the PBL approach are also reported.

Hong Kong Smart City Blueprint

Last year, Hong Kong government issued the “Smart City Blueprint” to propose measures to build Hong Kong
into a world class smart city. Plans of developing “Smart Living”, “Smart Environment” and “Smart People” were mapped out. These three areas are highly related to smart building engineering education.

Hong Kong is a technology-rich city. At this moment, the household broadband penetration rate of this city is 92.5% and its mobile subscriber penetration rate reaches 242.5%. The Hong Kong population is however ageing rapidly. It is projected that the population aged over 65 will increase from 16.6% of the total population in 2016 to 31.1% in 2036, which is causing a potential risk to this city. “Smart living” is therefore promoted such that more technology applications are adopted to support a healthy living style of the elderly.

In Hong Kong, 67% of carbon emission comes from electricity generation while buildings accounts for about 90% of electricity consumption currently. It is therefore necessary to create a “smart environment”. By promoting energy efficiency and conservation with the use of more smart technologies inside buildings, it is targeted that the carbon intensity of Hong Kong can be reduced by at least 65% by 2030 compared with the 2005 level, and people can enjoy better IAQ and a low carbon, more sustainable living environment.

Towards these two directions require “smart people”. Hong Kong government is promoting STEM education among the community to enhance the youngsters’ R&D capability. It is expected that in the near future, there will be a sufficient local supply of technology practitioners in Hong Kong and they could build up a knowledge-based society to support the smart city development of this city. VTC is nurturing smart people for building up the smart city.

Industry-based Student Project in IVE Engineering

VTC is a leading VPET provider in Hong Kong. IVE as its member institute is committed to nurturing talents to fully support the development of the city. We focus on equipping students with the competencies required in the 21st century, e.g. complex problem solving capabilities, creative and innovative thinking skills, communications and coordination abilities, etc. In the curricula of all IVE engineering programmes, every student has to complete an industry-based student project (IBSP) in an authentic or highly simulated engineering workplace environment.

On completion of the IBSP module, it is expected that students are able to:
- Integrate and apply knowledge and skills learned in the programme and experience gained from industrial attachment to solve engineering problems through different stages of development, including literature and information search, design, installation, testing, commissioning, evaluation and maintenance with exposure to current developments in building services engineering related industries;
- Implement relevant aspects of project management, for example scheduling, user requirements, costing, documentation, project supervision and coordination;
- Perform project tasks individually and as a team member to solve encountered problems with due reflection on safety, energy and environmental issues, and
- Produce formal written reports and give oral presentations explaining the project work.

Students will commence their IBSP at the beginning of the second semester of the final year of study and work on it full-time throughout the whole semester. Groups can be formed depending on the project nature despite individual assessment. Students are asked to demonstrate adequate research and planning capacities, project implementation abilities and reporting skills. The project work should be highly student-centred, in that students can gain knowledge through their own research and application of findings to solve problems associated with the work in a creative manner.

Conventionally, students will conduct the IBSP under a real industrial or commercial organization, but when it is not feasible, students can also opt to conduct their IBSP in campus. Similar work environment will be provided to the students who undertake in-house projects. To support the students, the project supervisor, who is a lecturer, will act as a mentor and guide the student throughout the IBSP.

In order to echo the government’s policy on pursuing smart city development, a team of six students studying in CE or BSE HD programmes was formed to undertake a project within the scope of smart building engineering education. The project aims to create a smart living style in an intelligent, sustainable and energy efficient building by using IoT control. Under the umbrella of this project, each of the six students is responsible for dealing with a particular aspect of the project for his own in-house IBSP so that at the end each of their works could be integrated to achieve the ultimate objective of the project. Figure 1 shows the systematic framework of the smart building engineering project.

Figure 1. The systematic framework of the smart building engineering project showing the scopes of work of the six students as highlighted in different coloured boxes.

The scope of work of each student is listed as below:
- Student A (BSE): Establish communications between LoRa terminal and lighting fixtures (in red);
- Student B (BSE): Establish communications between LoRa terminal and fan and HVAC system (in orange);
- Student C (BSE): Establish the relationships between IAQ parameters and IAQ sensors (in yellow);
- Student D (CE): Establish communications between WiFi and various smart wearables (in green);
- Student E (CE): Establish communications between WiFi and AV and other IoT control systems (in blue);
- Student F (CE): Establish the LoRa WAN system (in purple).

PBL projects require appropriate design and selection based on the learning outcomes desired. These projects must allow open-ended problem solving and application of theories. It is also an important criterion that the PBL projects allow for multiple solutions. A design problem usually has a number of solutions. Students can learn to evaluate these solutions and opt for the most suitable one for the situation. The PBL projects should give students sufficient freedom to explore the context, set the scope of work, identify the research sources and come up with a list of possible solutions. The project brief should not tell the students directly or narrowly specify a single solution. Students should instead select the most suitable solution based on the existing situations. The PBL projects should allow for considerations not limited to technical aspects, but also including economic, socio-cultural and ethical issues.

Students are encouraged to do their PBL projects with the sense of commercialization as it trains up students to handle real-world problems that they may encounter in their future professional careers. Also, the PBL projects should be designed in the way that, through working on the projects, students could learn to combine theoretical knowledge and practical experiences in new ways and build up a concrete foundation of knowledge and skills so as to lead to innovative but feasible solutions. The PBL projects should be designed ambiguous such that students could do research, think thoroughly the current situation and decide the tasks of various levels, the development direction, and the outcomes that they wish to achieve.

Last but not least, PBL encourages team work. Most real-world problems and their solutions are not of single discipline. Collaborations across disciplinary boundaries are usually required.

**Students’ work on the PBL-adopted IBSP**

The smart building engineering project was made up of six students’ PBL-adopted IBSP. Its ultimate goal is to develop a smart living system, equipped with IoT control, to be installed in a smart, energy efficient and sustainable building.

![Gateway (left) and LoRa terminal (right)](image)

Figure 2. Gateway (left) and LoRa terminal (right)

![Measured values by different sensors would be uploaded to Cloud for history record and graph plotting for easy reference](image)

Figure 3. Measured values by different sensors would be uploaded to Cloud for history record and graph plotting for easy reference

![Smart watch](image)

Figure 4. Flow chart of the operation of the smart watch

The system consists of four parts. The first two are the long-range radio (LoRa) gateway and the terminals. Figure 2 shows the gateway and the terminal that were used in the project. The LoRa gateway is the core of the whole project. It uses Arduino as the core processing
system and adds on the ESP0101 for connecting to the Internet via the web server. The LoRa gateway transmits commands to the terminals. The terminals receive data given by the various sensors, e.g. the values of light level, temperature and relative humidity, and send back the data to the gateway. The control part analyses the received data and implements different control strategies according to the situations. The third part is a wearable device control. Based on the human voice command, “Android wear” talks to the gateway and takes further actions. The last part is the indoor environmental quality (IEQ) system, also linked with gateways and terminals. It automatically monitors the various environmental data, such as CO2 and PM10, and controls the operation of some electrical appliances and keeps maintaining a good IAQ environment. Figure 3 shows a webpage of how the measured parameters are presented. Figures 4 and 5 show the flow charts of operating the smart watch and the LoRa terminal respectively.

Assessment for PBL

Assessing students’ performance in the PBL-adopted IBSP requires a special care in consideration of choosing an appropriate assessment technique suitable for PBL (Hosseinzadeh and Hesamzadeh, 2012). Real assessment is used to evaluate students’ performance. It is markedly different from the traditional exam which assesses the students at the end of a module; instead it evaluates the students’ performance over time regularly throughout their learning.

For obtaining a pass in the IBSP module, students have to pass 2 continuous assessment (CA) components: engineering competence and soft skills, and all 3 End of Module Assessment (EA) components. Students who are unable to complete the module for various reasons, or who fail to reach a satisfactory standard in any of the above components, are deemed to fail the module. Table 1 shows the assessment plan of IBSP.

<table>
<thead>
<tr>
<th>Continuous Assessment (CA)</th>
<th>60%</th>
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<tbody>
<tr>
<td>End of Module Assessment (EA)</td>
<td>40%</td>
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<tr>
<td><strong>Total</strong></td>
<td>100%</td>
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</tbody>
</table>

During the three-month PBL-adopted IBSP module, students are required to submit five types of assignments and conduct two presentations. These five types of work include one “reflection report”, nine “weekly project logs”, one “progress report” and one “final report”.

The “reflection report” demands students to write a short essay for illustrating that their achievements in the IBSP. The students should describe and provide evidence of how they have applied technical knowledge and professional skills that were learnt from classrooms in their PBL-adopted IBSP. Salient examples of applying interpersonal skills, teamwork skills, management skills, problem solving skills, and communication skills should also be provided.

“Weekly project logs” intend to let students reflect on their contributions to conducting the project, including the problems that they encounter and the solutions that they think of. Most important is that they should be aware of their own learning progress over time through this type of assignments.

The two reports and two presentations aim to assess whether the students could perform to a prescribed level as stated in the three module intended learning outcomes, i.e. research and planning, project implementation and project reporting.

Assessment rubrics provide clear criteria about how marks are allotted in the PBL-adopted IBSP. The rubrics give students a good idea of what is expected. Like what a previous paper highlighted, “Assessments need to take into account of appropriateness to the context of problem, how well the problem has been investigated, understood and resolved, the clarity of the definition of the problem, whether the solution space has been sufficiently explored, and how creative and innovative the solution is.” (Shekar, 2014).

Among the six students involved, one student got A, two got A-, two got B+ and one got B in their IBSP module. The good assessment results reflected that these six students performed well in their IBSP module and the intended learning outcomes of IBSP were satisfactorily achieved. Figures 6 and 7 show the rubrics of the IBSP Interim Assessment and Final Assessment respectively.
Student feedback

Student feedback about the implementation of PBL-adopted IBSP was obtained at the end of their study in two ways: (i) through a survey, alike the typical student feedback on a module, and (ii) from the part of students’ assignments, where students were asked to write a piece of self-reflection report on their learning experience in doing the PBL-adopted IBSP and how they achieve the learning outcomes of this module. The survey result on the satisfaction with the learning through the PBL-adopted IBSP was encouraging. The average overall score attained 8.2/10. Besides, the student’ reflection was very positive. For example, one of the students expressed his view that:

“Smart city development is an irreversible trend. It is nice for me to gain hands-on experience in building up a smart system with a group of team mates to solve the real-life problems about the elderly’s declining living quality and energy over-consumption in this city.”

Remark

This smart building engineering project obtained the champion of Chiang Chen Industrial Charity Foundation Student Project Competition (AY2017/18).

Conclusion

PBL is one of the recommended VPET pedagogies. It provides a wide range of credits to the students’ learning experience. For nurturing talents to develop Hong Kong to become a world class smart city, PBL was adopted in the IBSP module about smart building engineering. Six CE or BSE HD final year students under the supervision of three lecturers having different expertise backgrounds carried out the project as a team. Each student contributed a part via their IBSP in achieving the ultimate goal of the project, i.e. to develop a smart IoT control system for promoting smart living style in smart, energy efficient and sustainable buildings. The impact of using PBL as the teaching method was very positive. Involved students offered a high rating to the learning effectiveness of PBL-adopted IBSP module. Challenges of implementing PBL in IBSP are described in this paper. Assessment rubrics and the final product of the students in the PBL-adopted IBSP are also discussed. It is suggested that PBL should be widely adopted during the student learning process in the future.

References


AN APPROACH TO ENCOURAGE ALL KOSEN IN JAPAN TO USE THE EVALUATION INDICATORS OF ACHIEVEMENT IN ENGINEERING EXPERIMENTS

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Abstract

In Japanese higher education, there has been a great emphasis on guaranteeing the quality of education. Each school of the National Institute of Technology, Japan (NIT, or KOSEN) had individually been making an effort to enhance students’ experimental skills. However, there had been no consensus as to what kind of abilities students should acquire before they graduated, and it had been difficult for us to thoroughly ensure the quality of education. In order to solve the problem, KOSEN recently established the Model Core Curriculum (MCC), which clarifies the abilities and skills each student should acquire while at college whichever college they belong to. Moreover, in order to carry out the experimental section of the MCC properly, the present authors launched a project and developed a set of new indicators to evaluate the KOSEN students’ achievement in engineering experiments. The evaluation indicators are now used by only eleven out of fifty-one KOSEN colleges (Hakodate, Tsuruoka, Sendai, Oyama, Nagaoka, Kisarazu, Gifu, Suzuka, Niigama, Tokuyama, and Miyakonojo Colleges), which have participated in the project.

The aim of this paper is to introduce our new approach to spread the use of the evaluation indicators mentioned above to all KOSEN in Japan. System of our evaluation indicators consists of three parts. In the project, we first made a common guideline to make textbooks in all fields in engineering experiments; i.e., Mechanical, Material, Electrical and Electronics, Information, Chemistry and Biochemistry, Civil, and Architecture Engineering. The guideline proposes three levels of achievement (Level 1: knowledge and memory; Level 2: comprehension; and Level 3: application, which was determined based on the Revision of Bloom’s Taxonomy). Second, we made a total of more than 200 model textbooks on experiments based on the guideline. Third, we made evaluation sheets for each model textbook.

In our new approach to promote the use of the evaluation indicators, we made instruction books which show how to use the model textbooks and evaluation sheets we developed. In addition, we showed how to make new evaluation sheets for the experiment textbooks each Kosen had individually made before. We also propose the way to modify each Kosen’s original textbooks on experiment so that they can easily make evaluation sheets for the textbooks.

Keywords: engineering experiment, evaluation, achievement, KOSEN, model core curriculum, skill sheet

Introduction

The National Institute of Technology (NIT or KOSEN), which is an institution of higher education in Japan, offers a five-year unique education system for engineering. In higher education, there has been a greater emphasis on guaranteeing the quality of education. The model core curriculum (MCC) in KOSEN, which summarizes skills and attainment target outcomes, was released in 2012 as a tentative plan and in 2018 as a regular plan. The MCC list the skills that students should acquire over the course of their 5-year education, and the attainment levels for each skill (e.g., Kuroda, 2016; NIT).

It is one of the most important classes to do scientific experiments, workshop training, and practical manufacturing in the curriculum of KOSEN. Each KOSEN college had individually been making an effort to enhance students’ experimental skills. However, there had been no consensus as to what kind of abilities students should acquire graduating from KOSEN. Therefore, a standard way to evaluate engineering experiments throughout KOSEN has not been established.

Very recently, in order to carry out the experimental section of the MCC properly, the present authors launched a project and developed a set of new indicators to evaluate the KOSEN students’ achievement in engineering experiments. This is the first approach to be developed for many fields of engineering under a common guideline. (e.g., Takamura, 2017; NIT).

The evaluation indicators are now used by eleven KOSEN colleges, which are Hakodate, Tsuruoka, Sendai, Oyama, Nagaoka, Kisarazu, Gifu, Suzuki, Niigama, Tokuyama, and Miyakonojo Colleges, which have participated in the project.
Niihama, Tokuyama, and Miyakonojo. They have participated in the project named “Experimental Skill Project”.

In this report, we introduce our new approach to spread the use of the evaluation indicators mentioned above to all KOSEN in Japan.

Asahikawa experimental skill project

A project to develop evaluation indicators related to engineering experimental skills was begun in 2015. System of our evaluation indicators consists of three parts. In the project, we first made a common guideline to make textbooks in all fields in engineering experiments; i.e., Mechanical, Material, Electrical and Electronics, Information, Chemistry and Biochemistry, Civil, and Architecture engineering. The guideline proposes three levels of achievement. Second, we made a total of more than 200 model textbooks on experiments based on the guideline. Third, we made evaluation sheets for each model textbook.

The attainment targets in specialized skills required for engineers through specialized experiments are defined in the following 3 levels: Level 1 – knowledge and memory; Level 2 – comprehension; and Level 3 – application. These levels were based on the Revision of Bloom's Taxonomy (cognitive domains) (e.g., Anderson and Krathwohl, 2001). A rubric for experimental skills that did not depend on the field was proposed (e.g., Mitsui, 2016; Takeichi, 2016).

We also drafted a common guideline for textbooks on experiments in all fields of engineering. The following is an example of the guidelines: As a general rule, in a textbook for level 1, authors should write documents using a fill-in-the-blanks format or lists. For level 2, documents should be carefully detailed so that students can perform the experiments reading along with the textbook. Level 3 documents are written for those able to perform the experiments by themselves. Under the common guidelines for writing textbooks, we made “model textbooks for experiments” in the 7 fields of engineering.

A teacher should use the experimental textbook model and the experimental skill sheet in pairs for the evaluation. We also prepared a column for self-evaluation, to check students’ own sense of their attainment level. Table 1 shows typical experimental skill sheet for evaluation in electrical and electronics engineering. If an attainment level is different, the attainment target for the experiment also changes. For examples, in Level 1, students can perform the experiments by filling in the blanks of the textbook. Meanwhile, by Level 3, students can perform the experiments by themselves, even if they require a bit of advice.

Students carried out experiments and practised using the experimental textbook model and skill sheet at 10 KOSENs and in 7 fields of engineering. We also compared student self-evaluation results with those by the teacher. We produced more than 200 new teaching materials for engineering experiments (textbook models and evaluation sheets) based on our guideline in the 7 fields of engineering. A total of more than 2,000 students carried out experiments using our materials.

We assume that a teacher uses “model textbook for experiments” and “experimental skill evaluation sheet” in pairs for the evaluation, which calls them “the experimental skill set”

Instruction books to use the evaluation indicators

In our new approach to promote the use of the evaluation indicators, we made instruction books. They show how to use the model textbooks and evaluation sheets we developed. In addition, we showed how to make new evaluation sheets for the experiment textbooks each KOSEN had individually made before. We also propose the way to modify each KOSEN’s original textbooks on experiment so that they can easily make evaluation sheets for the textbooks.

The contents of instruction books are below:

- **Characteristic of the field**
  - It is written about each characteristic every field including thinking of the attainment level according to the field and the guidance policy of the experiment skill set.

- **Examples of experimental skill set**
  - It is shown as examples of the experimental skill set about attainment level 1 to 3, which we provided as a standard model of KOSEN. The experimental skill set becomes the pair of experiment book model and experiment skill evaluation sheet every attainment level.

- **How to use experimental skill set**
  - It is written about a method to utilize an experimental skill set provided when using it in each KOSEN.
    ① It is written about a point that pays attention when using as is.
    ② It is written about a utilized method of experimental skill set, when students cannot satisfy attainment target by each KOSEN’s original current experiment.
    ③ It is written about a utilized method of experimental skill set, when students can perform the experiment to level 2, but cannot satisfy an experiment of level 3.

- **How to make original experimental skill set**
  - It is written about a guidance to make a new experiment book and/or a new experiment skill evaluation sheet, using current experiment textbook in each KOSEN.
    ① It is written about a method to customize a current experiment textbook, and to make an experiment skill set.
    ② It is written about a method to just use the experiment textbook, and to make only an experiment skill evaluation sheet.

- **Others**
  - It is written about knowledge, the know-how that we notice during the project.
Table 1. Typical experimental skill sheet for the evaluation for attainment level 1 to 3 in the field of electrical and electronic engineering

<table>
<thead>
<tr>
<th>Experiment Theme</th>
<th>Electrical and Electronic</th>
<th>Achievement Level</th>
<th>Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning and Implementation</td>
<td>Bridge Circuit</td>
<td>(a)</td>
<td>3A</td>
</tr>
<tr>
<td>Preparation and Operation of Measuring and Equipment</td>
<td>Digital Multimeter</td>
<td>(b)</td>
<td>Being able to produce a bridge circuit on one's own.</td>
</tr>
<tr>
<td>Result / Analysis / Discussion</td>
<td>Balance: Conditions of Bridge</td>
<td>(c)</td>
<td>Being able to explain the experiment result from the balance condition of the bridge.</td>
</tr>
</tbody>
</table>

In order to encourage all KOSEN to use the evaluation indicators, we distributed instruction books to all KOSEN in Japan. In addition, we held a symposium, where instructors participated from 51 KOSENs. In the symposium, we made a presentation about evaluation indicators and discussed a problem of its instruction to each KOSEN.

Conclusions

The recent education reform in KOSEN sought to clarify the learning outcomes of each student graduating from KOSEN. Standards of quality assurance for experimental skills should be provided.

We produced more than new teaching materials for engineering experiments based on our guideline in the 7 fields of engineering. More than a total of 2,000 students carried out experiments using our materials. We clarified skills and attainment target outcomes that students acquired through the KOSEN engineering experiments.

We made instruction books in order to encourage all KOSEN in Japan to use evaluation indicators of experimental skill.

Acknowledgements

The authors would like to thank all members of Asahikawa Experimental Skill Project of National Institute of Technology.

References


EVALUATING EFFECTIVENESS OF INTERVENTIONS TO IMPROVE STUDENTS’ LEARNING IN ENGINEERING MATHEMATICS

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Abstract

This study aims to examine students’ learning experiences and the effectiveness of their learning in a classroom learning environment with interventions introduced to the module - Engineering Mathematics. The interventions involve two parts, (i) instructional design of the learning activities in the lesson packages and (ii) study skills of students. Feedback was gathered from 500 students through administering a survey questionnaire and a self-reflection checklist. To examine students’ learning experiences and the effectiveness of their learning, there are 3 main areas of consideration in this research: (i) students’ perception of the interventions made to lesson packages (ii) the level of effectiveness of these interventions on students’ learning (iii) the impact of students’ self-reflection checklist on their study skills.

This paper describes different methods and interventions that were introduced in the curriculum design of a polytechnic diploma first year math module for one semester - Engineering Mathematics. The interventions to the lesson packages include the introduction of digital interactive platform, Kahoot!, games and hands-on activities, Kahoot! was rated the highest for level of enjoyment by the students and is consequently perceived as the most important intervention amongst those introduced. Furthermore, its effectiveness to promote learning can be gauged. A strong relationship between the students’ level of enjoyment and students’ learning is observed. Among all these interventions, Kahoot! is the only digital interactive platform whilst the other interventions belong to the traditional non-digital hands-on activities. The findings of this research indicate that these interventions, especially those involving digital interactive platform, are able to promote learning effectively as they created more opportunities for the students to practise and demonstrate understanding.

Introduction and Background

Many believe that Mathematics is mainly about computations which is a common misconception. In application, these theories are used to create solutions for real life situations. In our current world, powered with advanced technologies, artificial intelligence and information predication, it has become an absolute necessity for people to be able to understand, analyse and apply appropriate mathematical knowledge. As learning and practicing students, it is necessary to be equipped with higher-order math knowledge to be successful in the engineering world.

The importance of adopting instructional design techniques by educators to obtain higher success math rates of students, in the aspect of higher achievement scores, is becoming significantly necessary. Rasmussen and Marrongell (2006) have also showed that it is important for educators to adopt instructional design techniques. They stated that after aligning students’ needs in obtaining higher-order math knowledge and abilities, instructional design can be used to provide a structural process and framework. Various studies indicate that instructional design is one of the more effective ways to remove challenges for a student in order to achieve math success. Saritas (2004) has indicated that instructional design is an effective way to alleviate many pressing problems in education, while Reigeluth (1983) shared that instructional design is a linking science – a body of knowledge that prescribes instructional actions to optimise desired instructional outcomes, such as achievement and effect.

However, instructional design per se cannot produce the other variables mentioned in this paper – including better learning and math achievements of students. The person designing the instructions (instructional designer) must possess clear understanding of crucial factors that affects students’ learning and build a bridge between the students’ achievement goals and their performance. Libienski & Gutierrez (2008) on the other hand stated that identifying these factors will help to utilise limited resources including financial resources and time more effectively. Once these factors are identified, there can be optimisation of financial and time resources.

In addition, students’ learning effectiveness is also dependent on their study skills. This is evident in a book titled “Conquering Math Anxiety” by Arem (2003). She has presented a comprehensive, multifaceted treatment approach to reduce math anxiety and help learner succeed in math.
In view of the above, this study explores the relationship between students’ learning experiences of the introduced interventions, and the effectiveness of their learning in a classroom learning environment for the module - Engineering Mathematics. The interventions involve two parts: (i) instructional design of the learning activities in the lesson packages and (ii) study skills of students.

Three main research questions of this study follows:
(i) What are the students’ perception on the interventions made to the lesson packages?
(ii) What is the level of effectiveness of these interventions on students’ learning?
(iii) What is the impact that students’ self-reflection checklist have on their study skills?

This action research study involved 1007 students of a polytechnic diploma taking first year math module for one semester - Engineering Mathematics over a period of 13 weeks at tertiary level. Students were exposed to the newly designed activities in every lesson over a period of 13 weeks. At week 6, a reflection checklist exercise was given to the students so as to evaluate their own study habits. They were given another 6 weeks to work on their study habits based on the checklist. Thereafter, they were given another round of this exercise at week 12 for them to assess their own progress. At week 7, the students were given a survey questionnaire to collect feedback on the interventions made to the lesson packages. These quantitative data points were examined and changes were made to the interventions if required. At week 13, feedback was collected from the students through the survey questionnaire again.

On the other hand, students’ learning effectiveness is also dependent on their study skills. This is evident in the work of Arem, her book titled “Conquering Math Anxiety” (Arem, 2003). She has presented a comprehensive, multifaceted treatment approach to reduce math anxiety and help learners succeed in math. Her approach to conquer Math anxiety involves: anxiety management and reduction, confidence building, success in math visualizations, learning-style enhancement, problem-solving strategies, effective math study skills and winning strategies for overcoming math test anxiety.

Under one particular aspect of her approach - effective math study skills, learners are to evaluate their own study skills using the self-reflection checklist. Thereafter, learners are required to streamline the strategies which they would like to improve upon, as stated within the checklist. This approach is proven effective as learners can always refer back to the checklist to see if they have made improvements in their study skills.

**Introducing Interventions in Lesson Packages**

Incorporating the ideas abovementioned, a series of interventions were introduced to the 13 lesson packages:

a) Having students demonstrate their learning and also have more questions creating more opportunity for the students to practise and perform using the interactive media: Kahoot! This is a platform whereby students come together to do questions in the same online platform.

b) Having extra questions through crossword puzzle and mini-game.

c) Presenting hands-on activities as a problem for the students to solve collaboratively.

**Achieving Effective Math Study Skills through Self-Reflection Checklist**

Arem (2003) came up with a self-reflection checklist on study skills in order to help learners to obtain effective learning of Mathematics. This checklist involves studying techniques that work best for math,
and she shared that by mastering these techniques, it will breed success. This self-reflection checklist exercises aims to help students to reflect on their study skills and to work on how to improve them so that learners are less anxious and can eventually learn better in class.

**Methodology**

The effectiveness of these interventions was measured by:

(i) The effectiveness of these interventions is underpinned by both quantitative and qualitative data points collected under consensus of the students. Student’s feedback on each aspect of the intervention within the lesson packages will be collected quantitatively through online survey questionnaire. The rating was based on a 5-point Likert Scale: 1 = Poor and 5 = Excellent. Feedback on the students’ perception on each aspect of the intervention was examined, together with their feedback on the effectiveness of their learning with the interventions. Meanwhile, students’ inputs on what can motivate them to learn and also other possible platforms to bring about more effective learning in their lessons were also collected.

(ii) To understand what impact the self-checklist exercise has on the students’ study skills, analyses was done on the students’ checklist scores - before and after, and reviewed if they have made any improvements in their score. Data on the usefulness of the checklist and if it has helped them to improve their study skills, were also be collected.

**Data Collection**

![Interactive online tool Kahoot!](image)

![Hands-on activities](image)

![Brain warm-up exercise](image)

![How much do all these activities help you to learn better in general?](image)

![How much do all these activities motivate you to learn the concepts for that day?](image)
Also, feedback on the usefulness of the self-reflection checklist and exam strategies in preparing them for their mid-semester assessment was collected and as shown:

![Figure 7: How useful did you find the timetable planning helps in your revision in preparation for mid-semester assessment?](image)

![Figure 8: How useful did you find the self-reflection checklist helps you to reflect on your study skill for this module?](image)

In both data collections, Kahoot! has the highest rating in its association to create an enjoyable learning environment for the students based on the feedback. For the first round of data collection, 80.68% of the students have given positive feedback that these interventions have helped them to learn better in general and 76.62% of them felt that these interventions in the lesson packages have also helped to learn the concepts for the day. 69.05% of the students have found the timetable planning useful in helping in their revision in preparation for mid-semester assessment. In addition, 67.84% of the students have found the self-reflection checklist useful in helping them to reflect on their study skills.

Actions taken after first round of data collection:

From the first round of data collection, the interventions have received positive feedbacks, thus these existing interventions were continued for the remaining 6 weeks. These interventions include: having Kahoot! for every lesson, re-assessing the students’ study skills through reflection checklist, sharing of strategies on how to cope with exam, sharing of brain warm-up exercise video and incorporating hands-on activities and mini-games in the remaining lessons.

In addition, in view of the students’ perspectives based on the feedback survey, it was noted that the lecturer also plays an important role in their motivation level to learn. Hence after, the lecturers introduced the sharing of motivational videos with the students on top of the usual guidance, and also more peer coaching and collaboratively learning in class when applicable.

![Figure 9: Select the activities which have helped you to demonstrate or apply the new concepts learnt. You can tick more than 1 option.](image)

![Figure 10: Which options which you find useful in your revision preparation for your assessment/examination? You can tick more than 1 option.](image)

Table 1: Data collected based on self-reflection checklist

<table>
<thead>
<tr>
<th>Students who have made:</th>
<th>Percentages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improvements in their study skills after the self-reflection checklists</td>
<td>81.23</td>
</tr>
<tr>
<td>No changes in their study skills after the self-reflection checklists</td>
<td>18.77</td>
</tr>
<tr>
<td>Improvement in their scores</td>
<td>44.31</td>
</tr>
<tr>
<td>Drop in their scores</td>
<td>48.69</td>
</tr>
<tr>
<td>No changes in their scores</td>
<td>7.01</td>
</tr>
</tbody>
</table>
In the second round of data collection, Kahoot! has the highest rating to create an enjoyable learning environment for the students based on the feedback and it is also rated the highest among all the activities in the effectiveness of learning. 76.06% of the students have given positive feedback that these interventions have helped them in their learning and 72.98% of them felt that these interventions in the lesson packages have also helped to motivate them to learn the concepts during lessons. In addition, 81.23% of the students feedback that the self-reflection checklist have helped to improve their study habit, however, when comparison was made between the students’ scores between their two self-reflection checklist exercise, only 44.31% of the students have improvements in their scores. There was observation made from the data that the students did make attempts to improve their study skills but it was not significant enough to result in an improvement in the score. On the other hand, more than 50% of the surveyed students found the interventions useful in helping them for their examination preparation with the strategies on how to cope with Math examination being ranked the highest.

In addition, feedback was collected on the reasons for their motivations and also their sharing of activities which they viewed is able to help them to learn better: Lists of reasons that will motivate the students to learn better for both rounds of data collection are (in no particular order): good grades, lecturers, interactive activities such as Kahoot!, games, friends and peer supports, more given examples and questions, prizes and rewards, and individual goals.

List of activities which the students suggested to have to promote learning from both rounds of data collection (in no particular order): more brain exercises, videos about the topic being taught, interactive games, Kahoot!, e-learning lesson, real life scenarios to relate their problem, stress-relief activities so that they can concentrate better when studying, peer-to-peer guidance, hands-on activities and lastly, different learning environments.

The list of activities suggested by them and also the reasons for them to be motivated to learn are quite similar in both rounds of data collections. The top factors for the students to learn are good grades, lecturers and peers, and challenging questions. On the other hand, the top suggestions proposed by them which they think can help them in promoting their learning are to have more math games and activities, more questions or quizzes and also more Kahoot! and hands-on activities.

Through the qualitative feedback, one observation made was that the interventions have made an impression on the students as many of the interventions are being raised up as part of their suggestions for further improvements to promote their learning.

Conclusions

In this paper, different methods were explored and interventions were introduced in the curriculum design for Engineering Mathematics. Kahoot! is being perceived as the most successfully implemented intervention as it was rated the highest for level of enjoyment by the students and also its effectiveness to promote learning. A strong relationship between the students’ level of enjoyment and students’ learning is observed. Among all these interventions, Kahoot! is the only digital interactive platform as compared to the other interventions which belonged to traditional non-digital hands-on activities. The findings of this research indicate that these interventions, especially those involving digital interactive platform, are able to promote learning effectively as they created more opportunities for the students to practise and demonstrate their understanding after given examples as emphasised by Gardner (2009), and Perkins and Unger (1999).

From the data collected, the self-reflection checklist on study skills was able to help students reflect on their study skills and got them to continually work on improving their study habits. However, the efforts put in to improve their study skills are not significant enough to be reflected as an improvement in the checklist scores during the second round of exercises. This study can probably be improved if there is more monitoring and follow up on the students’ study skills by their lecturers in between the two rounds of self-reflection checklist exercises.

Through the qualitative feedback, the most cited reasons for students’ motivation are good grades, lesson activities, lecturers and friends. For this action research, the study focused more on instructional design of the lesson packages to promote learning. For further studies, more interventions can be explored to work on how to improve the students’ motivations and learning in Engineering Mathematics.

Acknowledgements

Special thanks to the School of Engineering and Centre for Educational Development, Republic Polytechnic Singapore for the resources and information provided in this paper.
References


Annex A: Self-Reflection Checklist on Study Skill

<table>
<thead>
<tr>
<th>How Good Are Your Study Skills?</th>
<th>Usually</th>
<th>Sometimes</th>
<th>Rarely</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I intend all my Engineering Mathematics classes.</td>
<td>(3 points)</td>
<td>(2 points)</td>
<td>(1 point)</td>
</tr>
<tr>
<td>2. I mentally follow all explanations, trying to understand concepts and formulas.</td>
<td>(3 points)</td>
<td>(2 points)</td>
<td>(1 point)</td>
</tr>
<tr>
<td>3. I usually write down main points, check in explanations, definitions, examples, solutions, and proofs.</td>
<td>(3 points)</td>
<td>(2 points)</td>
<td>(1 point)</td>
</tr>
<tr>
<td>4. I review my Math class notes again 2 to 3 hours later or definitely the same day.</td>
<td>(3 points)</td>
<td>(2 points)</td>
<td>(1 point)</td>
</tr>
<tr>
<td>5. I do weekly and monthly reviews of all my Math class notes.</td>
<td>(3 points)</td>
<td>(2 points)</td>
<td>(1 point)</td>
</tr>
<tr>
<td>6. I work on at least ten new questions and five reviewed questions during each study session.</td>
<td>(3 points)</td>
<td>(2 points)</td>
<td>(1 point)</td>
</tr>
<tr>
<td>7. When I read, I say aloud and write out important points for a particular Math concept.</td>
<td>(3 points)</td>
<td>(2 points)</td>
<td>(1 point)</td>
</tr>
<tr>
<td>8. I underline, outline, or label the key procedures, concepts, and formulas in my text.</td>
<td>(3 points)</td>
<td>(2 points)</td>
<td>(1 point)</td>
</tr>
<tr>
<td>9. I take notes on my text and review them often.</td>
<td>(3 points)</td>
<td>(2 points)</td>
<td>(1 point)</td>
</tr>
<tr>
<td>10. I want to complete all my Math quiz and homework.</td>
<td>(3 points)</td>
<td>(2 points)</td>
<td>(1 point)</td>
</tr>
<tr>
<td>11. I complete all my Math quizzes and homework and keep up with my class.</td>
<td>(3 points)</td>
<td>(2 points)</td>
<td>(1 point)</td>
</tr>
<tr>
<td>12. I want to ‘overlearn’ and thoroughly master my Math material.</td>
<td>(3 points)</td>
<td>(2 points)</td>
<td>(1 point)</td>
</tr>
<tr>
<td>13. I want to integrate with other to solve the question in memory.</td>
<td>(3 points)</td>
<td>(2 points)</td>
<td>(1 point)</td>
</tr>
<tr>
<td>14. I want to understand all formulas, terms, rules, and concepts before I memorize them.</td>
<td>(3 points)</td>
<td>(2 points)</td>
<td>(1 point)</td>
</tr>
<tr>
<td>15. I use a variety of checking procedures when solving Math questions.</td>
<td>(3 points)</td>
<td>(2 points)</td>
<td>(1 point)</td>
</tr>
<tr>
<td>16. I study with two or more different Math sources for references.</td>
<td>(3 points)</td>
<td>(2 points)</td>
<td>(1 point)</td>
</tr>
<tr>
<td>17. I study with two or more different Math sources for references.</td>
<td>(3 points)</td>
<td>(2 points)</td>
<td>(1 point)</td>
</tr>
<tr>
<td>18. I take short breaks every 20 to 40 minutes when I study Math.</td>
<td>(3 points)</td>
<td>(2 points)</td>
<td>(1 point)</td>
</tr>
<tr>
<td>19. I study Math before other subjects when I need to study.</td>
<td>(3 points)</td>
<td>(2 points)</td>
<td>(1 point)</td>
</tr>
<tr>
<td>20. I reward myself for having studied and concentrated.</td>
<td>(3 points)</td>
<td>(2 points)</td>
<td>(1 point)</td>
</tr>
</tbody>
</table>

Totals: My Grand Total is:
Abstract

The Innovation pedagogy and the CDIO approach are the key elements in engineering education in the Turku University of Applied Sciences. Based on these approaches four main goal categories have been defined: structures, learner, teacher and culture. These categories are further described with concrete goals for the engineering education. For example, structures are described with words such as flexibility, learning with the industry, projects and multidisciplinary. In general, the acquisition of knowledge and development of skills go hand in hand in our programs. In curricula, there are faculty wide agreement that each program has certain elements raising from the Innovation Pedagogy, CDIO approach and the detailed goals we have defined. There are for example Project Hatchery, Introduction to your own study field – module and Innovation Project. In general, the basic elements of our education are in good condition. At the same time, the economy of the region is booming and there is a high demand of skilled engineers. The engineering faculty realized that we have to do better to answer the needs in the region and in the working life. Therefore, we organized a series of workshops to discuss how we could do better. Altogether 66 staff joined the workshops in spring 2018. First part of the workshops focused on the current challenges and the second part on finding answers and solutions to these challenges. The findings emphasized supporting students’ intrinsic motivation and importance of teachers’ pedagogical and coaching skills among others. In this paper, the pedagogical playground of our programs is described as well as the challenges and the proposed solutions from the workshops.

Keywords: Innovation Pedagogy, CDIO approach, Engineering education, Challenges

Introduction

Turku University of Applied Sciences (TUAS) is an inspiring community of 10,000 members – an innovative and multidisciplinary higher education institution, which creates international competitiveness and well-being for Southwest Finland. Our graduates are practice-oriented professionals with top competencies. Turku University of Applied Sciences has three faculties of which the Faculty of Engineering and Business is the biggest with 5800 students. In the field of applied research, Turku University of Applied Sciences represents the top tier in the country. TUAS coordinates or acts as a partner in over 200 RDI projects yearly. Studies at TUAS are working life-oriented, combining theoretical studies with professional skills. At the core of our teaching is Innovation Pedagogy, a new approach to learning developed at TUAS. Innovation Pedagogy emphasizes the viewpoints of RDI and working life, making our graduates independently minded professionals with excellent international and communication skills. In the approach, learning and teaching methods are applied creatively and, in a value-adding way, so that the students take responsibility for their learning and actively strive to reach their learning goals (Konst & Scheinin, 2018). Innovation pedagogy has a key role in the TUAS strategy and CDIO approach links very well with it (Penttilä & Kontio, 2014, 2016; Penttilä, Kontio, Kairisto-Mertanen, & Mertanen, 2013). Turku University of Applied Sciences (TUAS) has been a member of international CDIO initiative since 2007. The Faculty of Engineering and Business uses the CDIO approach together with Innovation Pedagogy to respond to the needs of the industry.

The goal of CDIO approach (Crawley, Malmqvist, Östlund, Brodeur, & Edström, 2014) is to (a) educate students that have deep working knowledge of the technical fundaments, (b) are able to lead in the creation and operation of new products and system and (c) are able to understand the importance and strategic value of their work. The CDIO approach is adaptable to all engineering schools, but other fields of education can learn from CDIO approach too. The key elements of teaching and learning in CDIO are the connection to the working life and real engineering practices and active involvement of students in their learning. The CDIO approach supports universities and programs in education development by offering tools (CDIO standards and CDIO syllabus) for continuous improvement. The 12 CDIO Standards address program philosophy (Standard 1), curriculum development (Standards 2, 3 and 4), design-implement experiences and workspaces (Standards 5 and 6), methods of teaching and learning (Standards 7 and 8), faculty development (Standards 9 and 10), and assessment and evaluation (Standards 11 and 12) (Crawley, Malmqvist, Östlund, Brodeur, & Edström, 2014). The CDIO syllabus provides key competences for engineering programs...
Besides the core technical topics, the general objective of the CDIO Syllabus is to describe a set of knowledge, skills and attitudes desired in a future generation of young engineers. It offers rational, complete, universal and generalizable goals for undergraduate engineering education.

Following the ideas of the Innovation pedagogy and the CDIO approach we have defined four main goal categories (Figure 1): structures, learner, teacher and culture. The work of Goldberg and Somerville (2014) has influenced on the categories broadly too.

![Figure 1. Key goals in education](image)

Each of these categories are further described with more concrete goals for our degree programs and the faculty operations altogether. Structures describe the key ideas on how we organize our teaching and learning. The curricula are flexible. They define the overall competences for the degree, but allow flexibility on the modules and courses our students do. Teaching and learning is done together and in the industry. The teaching and learning is filled with projects and multidisciplinary activities. The Learner category has two key elements. First, we have to enable the learners’ intrinsic motivation to get them wholly engaged resulting to deeper and more effective learning. Second, we have to allow student to make individual study choices and paths to build their expertise. Giving students the power of controlling the elements of their education they feel the trust and are motivated on their learning. Third, our teachers have strong practical experience from the industry and we want them to be able to support the learning of our students with coaching capabilities. The teaching follow the principles of experiential and active learning where student has the key role in learning process and our lectures coach them in their learning process. The teachers need good connections to the working life and these connections has been maintained. Finally, all the above has impact on the culture of the faculty. The teaching, learning and working environment and atmosphere need to change. We are requiring more, we are working as a community and entrepreneurial activity is increased. In general, the acquisition of knowledge and development of skills go hand in hand in our programs. In curricula, there are faculty wide agreement that each program has certain elements raising from the Innovation Pedagogy, CDIO approach and the detailed goals we have defined. There are for example Project Hatchery (Kumpula, 2014), Introduction to your own study field – module and Innovation Project (Kulmala, Luimula, & Roslöf, 2014).

In general, when HEIs want to develop their education and aim for better graduates they can identify three questions that a higher education institutes has to think (Crawley et al., 2014). First, they have to be aware of the need of their graduates - What is the professional role and practical context of the profession(al)? Second, the learning outcomes of their program has to be defined in relation with the needs in the industry - What knowledge, skills and attitudes should students possess as they graduate from our programs? And third, there is always room for improvement in the producing of the learning. It is possible to reconsider the curriculum, teaching and learning activities, assessment and workspaces and learning environments - How can we do better at ensuring that students learn these skills? Kamp (2014) encourages higher education to make fundamental changes, to take the benefits of the pedagogical and technological innovations, and better prepare graduates for the increasing and different demands of the new world of work.

The recent report (Kamp, 2014) aimed to look the global state of the art in engineering undergraduate education. She tried to identify the current and emerging leaders in engineering education and their distinctive features. Finally, the study reported the key challenges that are likely to constrain the progress of engineering education. Graham’s report lists several distinctive pedagogical features that the recognized current leaders in engineering education share. First, the students must have opportunities to engage with the university’s research activities often building on applied teaching in the engineering fundamentals. Second, there are wide range of technology-based extra-curricular activities and experiences available to students and many of them are student-led. Third, there are multiple opportunities for hands-on, experiential learning throughout the curriculum. These learning experiences cover often both problem identification and problem solution and they are supported by state of the art engineering workspaces. Fourth, user-centric design is used throughout the curriculum enhancing students’ entrepreneurial capabilities. Fifth, the leading universities provide emerging capabilities in online learning and blended learning. Finally, the collaboration and partnership with industry in education and in research is longstanding.

In Southwest Finland the economy is booming and there is a high demand of skilled engineers. The marine, medical, automotive and other fields of technology industries are all growing rapidly. This positive structural change sets pressure to our university too. We are actively building a technical innovation university of the future. We are investing in new research and development infrastructure to support the structural change in the region. Our communication and collaboration with the industry is active. We work together in research and development projects, they participate as visiting lectures in teaching and our advisory boards provide a forum to discuss the future trends and the needs in industry. Thus we have the understanding of the professional role and practical context of our professionals. The learning outcomes are discussed constantly with the industry representatives as well. We are constantly working on to ensure that our students have the needed knowledge and skills when they
graduate. We have approached this demand from different viewpoints such as the curriculum structure and content, teaching and learning methods in use, hands-on experiential learning experiences, level of engineering workspaces and faculty competence. Despite all the activities we still have the feeling that we can do better to answer the needs in the region and in the working life. Therefore, we organized a series of workshops to discuss how we could do better. This paper presents the work and results focused on this regional demand.

**Research**

The idea of having How to do better –workshops was introduced in a faculty meeting in February 2018. An open invitation to join was presented in the meeting to all faculty members. Participation into the workshop was voluntary and everyone was free to join.

Altogether five workshops were organized in the beginning of March 2018. Each workshop followed the same procedure and lasted two hours. A total of 62 teachers (30% of the faculty) and 4 student representatives joined the workshops. In the workshops the participants worked in randomly created groups of around 5 to 6 persons.

The workshops covered two themes: Current challenges and Solutions to the selected challenges. The beginning of the workshop was dedicated to identify the challenges in our activities that hinder us from not reaching the best results. After listing randomly the challenges, the workshop participants were asked to select the challenges that they would like to present some solutions. The second part of the workshop focused on creating possible solutions to the selected challenges and finally closing the workshop on a common discussion.

Every workshop was documented and after all five workshops the author summarized the results using content analysis. Content analysis is a research technique for systematically analysing written communication such as the workshops reports in this paper (Weber, 1990). Content analysis allows the researcher to analyze relatively unstructured data in view of the meanings, symbolic qualities, and expressive content (Krippendorff, 2012). In content analysis all answers are processed and interesting and relevant information is collected. Once all answers are processed major themes and categories are identified.

**Identified challenges**

In the workshops 73 single challenges were identified. These challenges were grouped into 10 groups that are not totally distinctive rather have some overlap. These ten groups correspond well with the key goals of our education (see Figure 2). The challenges dealing with the structures were tutoring and guidance, multidisciplinary, student enrolment and curricula related structures.

The workshops participants provided following challenges in tutoring and guidance:
- We are not able to keep the level of learning, because we are focusing too much on the low motivated students
- There are not enough support for the teacher to succeed in tutoring and
- The competence levels in a student cohort are very broad and far away – according which level we go?
competence lack needs to be fixed before focusing master level studying.

Only one group of challenges was identified for the teacher: faculty competence. First, the participants expressed their worry that our personnel doesn’t share the overall understanding of the education focus and context. Second, the world is changing so quickly that our teachers’ competences need updating too. Third, the motivation of teachers is as important as students – how we keep up the working capacity and enthusiasm?

Finally, there were three challenge groups addressing the culture. These were the teaming of the students and community spirit, constant change and low completion of studies. The participants of the workshops discussed much about the teaming of the students and how important that is. They shared the idea that there might be too many teams and groups a student has to cope with. Can we create teams or groups that encourage studying and commitment to studies? The teaming of the students could help community building too, but how to support community spirit in online learning? A question was raised whether our tutor groups are too large thus not serving the teaming and commitment. We are building a new campus and it was seen as a challenge and a possibility at the same time to build community spirit.

Another challenge with the culture was the feeling of constant change. The workshops discussed that we have had too many changes and we have been too innovative – are they actually slowing down our development. They expressed a worry that maybe with the changes we are losing the characteristics of the programs. The participants asked for better use of existing information and regional economy forecasts.

One big challenge that is not unique to our faculty is long graduation times. For example, students in engineering should graduate in four years, but the norm is closer to five years. Another challenge here is that the number of students that eventually graduate is much fewer than the number of students that started the studies. A more positive challenge is that students are hired to industry before they graduate which is not the optimal situation either.

Suggested solutions

Based on the challenges each workshops produced they continued to propose solutions too. Solutions were proposed for motivation of students, student competences, guidance and tutoring, beginning of studies, structures, enrolment, pedagogy and master studies.

The motivation of the students can strengthen with following actions and ideas. We invest in the learning environment and make it more attractive – there are cafeterias and maybe there is even free coffee available. We collaborate more with our alumni and connect them with our current students. We organize large projects and events that support community spirit and motivation. And we need to communicate more on the future job opportunities and requirements.

The competence level of students is partly not good enough in basic mathematics and physics. It is proposed that we offer an extra course for students having low skills on basic natural sciences. In addition, we have to find a way to differentiate study groups based on the skill level. This enables to support the students with low skills more and on the other hand speed up studying with the others.

There was several ideas how to do better in tutoring and student guidance. One possible solution could be that students from the older cohort work together with students in younger cohorts. We could define clearly how the older ones support and assist the students in the younger cohorts. Furthermore, we have to think about groups sizes in tutoring and in teaching and learning too. Maybe there is room for prioritizing the tutoring and guidance resources to students that are more like to graduate. Altogether, tutoring should build the path to the profession better.

The beginning of studies is usually very important to learn the right way to work and study as well as team up with the fellow students. The workshops propose that we start with real projects from the day one. We should place more effort on making the first year. We should have the first year students more tightly in our control and let them gradually learn the freedom of the studies. In addition, students should have the feeling of their own expertise very early on their studies.

We have developed our curricula continuously and the workshops encourage us to continue that work. The workshops identified certain very concrete proposals to curricula development. For example, we should get rid of the mandatory 5-credit size of courses. We should also provide more study-field specific elective modules. A big possibility is to utilize summer semester more efficiently.

The improvements to student enrolment asked for better profiles of the programmes and their specialisations. We have to make sure that the language is correct for the young generation thinking about applying to us. Another interesting idea was to establish a summer academy together with selected industry partners. All students who pass the summer academy will be granted a study place. The summer academy will be planned together with selected industry partners and the projects and topics could even continue after the summer as normal first study year parts of the degree program. The summer academy could even lead to summer employment or internship in the company.

The workshop proposed number of improvement activities in our pedagogy too. Each teacher should reflect his/her teaching methods and think about the appropriateness of them to the defined learning outcomes. As valuable is to reflect the assessment practices with the teaching and learning activities. Basically the workshops reminded the constructive alignment concept (Biggs, 2003), which connects the intended learning outcomes, teaching and learning activities, and assessment of student learning. Furthermore, the workshops required that we emphasise more on giving feedback. The feedback should be more versatile and timed better as well as it should focus on improving the skills of the student.

The workshops focused more on Bachelor level issues, but some ideas we proposed for master studies
too. As part of their challenge of long graduation times, the master thesis is usually the most typical reason for not graduation on time. Therefore is was proposed that the thesis should be started much earlier, it should be guided and checked more often and there could be peer thesis groups. Regarding the student enrolment challenge, we have to market the different study possibilities better. In addition to traditional master programs we have master studies in our research groups. There are differences on applying the programs, on the study format and on the timing of the studies. These differences should be explained better for the possible master student candidates.

Discussion

The five How to do better – workshop offered a very good platform for open discussion on our way of teaching and learning. The challenges that the workshops identified corresponded quite well with the goals that we have defined. The four goals of structures – flexibility, learning with the industry, projects and multidisciplinary – were partly identified as challenges still. We could do better with the flexibility and multidisciplinary. On the other hand, learning with industry and projects were not mentioned suggesting that these elements are all right. The key goal of the learner category is to enable the students’ intrinsic motivation. Unfortunately, the workshops suggest that we still have a way to go here. For the teachers we have defined two goals: they have strong practical experience from the industry and they are able to support the learning of our students with coaching capabilities. The workshops emphasized that we need to update the practical experiences of our faculty and support their pedagogical skills and understanding of the programs. Our fourth category of goals is about the culture. The way we operate in our daily teaching and learning, how we work as a community with entrepreneurial activities present. Based on the workshops our efforts on building a community and team spirit have not been enough, neither have we succeeded in communicating the development actions and their rationale.

Based on the challenges the workshops proposed possible solutions to do better. Some of the proposed solutions are such that we are already working with, but there were very concrete and new ideas presented too. The proposals are discussed in below:

1. Learning environments
   • New campus in process and to be ready 2020
   • New investments (7 million euros) on laboratory infrastructures is decided

2. Alumni activities
   • Some programs have active alumni network already, but this is not a faculty wide habit at the moment

3. Large projects and events that support community spirit and motivation
   • Several large projects and events are already organised annually and we will continue this and maybe introduce new events too

4. Extra support for natural sciences
   • This needs to be further discussed and planned

5. Tutoring and guidance changes
   • We can use students from the older cohorts to guide students in the younger cohort more than we currently do.
   • Use of students might help with the group size challenges too.
   • We have decided that we renew our tutoring model in 2019 and move tutoring closer to daily teaching and learning.

6. Real projects from the beginning of studies
   • The curricula 2019 of the faculty will have project hatchery –module in the first semester.

7. Own expertise from the beginning
   • The curricula 2019 of the faculty will provide Introduction to you own study field as a project module in the first study year.
   • This follows the CDIO standard 4.

8. First year more controlled
   • Both above mentioned project modules will support a more controlled first year studying.

9. Summer semester
   • The responsibility of summer semester content has moved to the faculties and summer 2019 is the first where faculties can create a summer semester answering better to their program requirements.

10. Summer academy
    • This proposal is very interesting and we need to discuss more about this.

11. Marketing of our programs
    • We have changed the way our program descriptions are produced. We have standardized key elements of our teaching and learning descriptions and make sure that our texts address possible students better.
    • Enrolment is changing nationwide too. More emphasis will be given to the matriculation exam results and traditional entrance exams will mostly be removed.

12. Pedagogical support
    • Our university provides trainings on Innovation pedagogy and online learning. Faculty members are encouraged to join these.

13. Focus on feedback
    • This is an activity for each faculty member to reflect their own way of teaching and learning.

14. Master studies
    • We reorganize our master education in new Master School of Engineering and Business in the beginning of 2019. This new organization will work on the identified challenges and the proposed solutions.

The discussion we had in our workshops provided us good understanding on our challenges and ideas on how to do better. It is interesting to notice that our discussions, our goals and our activities have many similarities with the distinctive features of the engineering education leaders as presented in the Graham's (2018) report. As a leading university of applied sciences in Finland our
applied research provide plentiful opportunities to our students to engage real research activities connected with their learning. Our curricula are filled with multiple opportunities for hands-on, experiential learning and with the new investments and new campus our workspaces and infrastructure support these activities. Our partnership with the industry is strong both in education and in applied research. We do have elements supporting entrepreneurial capabilities too, but there we still have more work to do. Use of online learning and blended learning is starting and we have good examples of successful programs utilizing these, but this is not the main stream and our university supports this with the pedagogical trainings offered. Most work is needed to get a range of student-led technology-based extra-curricular activities and experiences available.

Still, we can argue whether the steps we are taking are enough to take the benefits of the pedagogical and technological innovations, and better prepare graduates for the increasing and different demands of the new world of work like Kamp (2014) proposes. Anyway, we answer quite well with the future direction of engineering education (Graham, 2018). Our curricula are flexible and provide possibilities for students to build their own expertise, there are many possibilities for multidisciplinary learning, and learning is supposed to happen outside the classrooms too.

Conclusions

Our activities supported with the Innovation pedagogy and CDIO approach have taken us into right direction. The elements of Innovation pedagogy and CDIO approach are visible in our curricula and in our teaching and learning. Both have given us a structure and support to proceed in our development activities. Still, we are not there yet as our workshops showed. There are several challenges and suggested actions how to do better. We have processed there results further in a faculty wide workshop together with 250 faculty members. Our faculty management team will continue processing the original results and the follow-up workshop results in autumn 2018.

The possibility to discuss freely about our challenges and provide suggestions to answer these challenges was very positive experience and we can recommend this to other institutions too. Our faculty will continue discussions/workshops in the autumn with no-agenda format.

References


Abstract

The hands-on experience that was once thought of as key to creating a well-shaped student has now disappeared from the classroom. Hands-on Learning isn’t just for sewing, cooking or painting; it could be for subjects in science as well. In this paper, we present the phases of creating a hands-on experience for students in learning advanced networking technologies in their final year projects. Students were grouped (3-4 students per group) and were asked to prepare a project related to the Internet of things (IoT). IoT is the network of physical devices embedded with electronics, software, sensors, and network connectivity which enable these objects to connect and exchange data. IoT recently incorporated into our daily living that makes our life more comfortable. However, many previous works do not consider the need of people with disabilities, and the cost of building up a smart home can be very expensive. A group of students proposed a low-cost smart home especially for people with disabilities and pet owners. The smart home has four main features: (1) Effective temperature & humidity monitoring by using DHT11 temperature sensors; (2) Pet / disabled / elderly monitoring by using Arduino robot car; (3) High security by using RFID and (4) Health monitoring by using pulse sensors. This low-cost system can give users real-time reactions or important warning messages. Besides, the data collected by the system will be sent to the data server for further peruse if necessary. During the project, the teacher acts as a supervisor to guide students in forming the project, writing up proposal, implementing the project, solving problems they faced and organizing tasks. Through this, students have the opportunity to develop their skills, collaborate as a team, gain knowledge on designing and making functional products, and practice their public speaking skills. In this paper, we will introduce each part of the smart home and their functions. Besides, we will describe what problems the students faced during each stage of the project and how they solved their problems.

Keywords: Hands-on, Technology, IoT, Smart Home, Sensor, Robot car, automated system

Introduction

As technology grows exponentially in the past two decades, a number of previous works proposed many learning framework for students to learn the latest technology. Yu and Lin proposed an online learning system which first presents the theoretical concepts of Mathematics, Science, and Technology (MST) to students, and then provides an online simulation to help students utilizing the concepts to design virtual products of MST, and finally requires students to design and make the real products in order to integrating concepts learned with practical problem (Yu & Lin, 2017). Rutten et al. pointed out that computer simulations can enhance traditional instruction, but it is also necessary to consider the possible impact of teacher support, the lesson scenario, and the computer simulation's place within the curriculum (Rutten, van Joolingen & van der Veen, 2012). Cruse proved that using educational video in classroom teaching is an effective way to help students to understand the teaching materials, and it is important to take into account the length of video (Cruse, 2006). In this paper, we propose to guide the students to learn practical skills by using educational video outside classroom and working on hands-on projects to link up the concepts and practical problems. We found out that educational video is a very good resource to help students to learn hands-on skills. Besides, watching video outside classroom can further motivate students' learning interest because students can watch the videos at anytime, anywhere. However, students need to have some basic theoretical background, which can only be learned from classroom, in order to understand the skills taught in videos.
<table>
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<tr>
<th>Step 1: Empathy</th>
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| ◆ Gain insight on needs through interviewing people with different needs and pet owners, normal users, and pet owners.  
◆ Consider in detail on how IT technology can help with the people needs. | EMPATHY |

<table>
<thead>
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<th>Step 2: Define</th>
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| ◆ Improve people’s living by making use of the advanced technology.  
◆ Offer more convenience by allowing users to remote control the device.  
◆ Detect and update the temperature and humidity information timely with the sensor. | |

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<th>Step 3: Ideate</th>
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| ◆ Explore useful functions for people with different needs such as provide navigation for the visually impaired with the robot car.  
◆ Explore useful functions for pet owners such as allow users to remote control the robot car to walk around and exercise with their pets.  
◆ Explore more timely reflection of temperature and humidity information for users. | |

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<th>Step 4: Prototype</th>
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| ◆ System functions were coded by development tools such as Visual Studio and Arduino IDE.  
◆ The above tools are developed by C/C++ programming language in order to instruct the sensor to perform required functions. | CODE |

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<th>Step 5: Test</th>
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| ◆ Perform module test to validate individual system component.  
◆ Conduct user acceptance test (UAT) to justify system usability. | Test |
**Materials and Methods or pedagogy**

Doing hands-on projects is a common methodology to help students to learn practical skills. Before working on the projects, students have to learn the basic technical concepts in classroom and these knowledge can help the students to further explore themselves to develop the real products outside classroom. However, contact hours in classroom are limited. Online learning materials might be a good resource to help students to learn by themselves, and online educational videos attract the most attention from learners. It is because students can watch the videos at any time, anywhere.

In this case study, a group of 4 final year students from Higher Diploma in Telecommunications and Networking worked on their final year project for 9 months. During their Year 1 study, the students have learned some basic technical modules, such as Network Fundamentals, Introduction to Programming, Web Application Development Frameworks, Telecommunications & Networking Project and so on. After group formation, the students adopt the Design Thinking Model (Denning, 2013) in their project work as shown in Table 1.

- **Step 1 – Empathy.** Students have to brainstorm what project topics they have interest to work in. They need to think about how IT technology can help with the people needs.

- **Step 2 – Define.** Students have to define they project topic with the consent of their supervisors.

- **Step 3 – Ideate.** Students have to write up their project proposal which includes the project scope, targeted users, project deliverables, division of tasks and project timeline.

- **Step 4 – Prototype.** Students have to develop the smart home system with sensors of various functions and the online system for data collection and analysis. In this stage, students needs to integrate what they learnt in classroom into practical real scenarios.

- **Step 5 – Test.** Students have to perform module test to validate individual system component. They have to carry out integrated system test to validate the system performance as a whole. They also need to conduct user acceptance test to justify system usability.

**Results**

The students successfully design and produce the IoT system within 9 months. Figure 1 shows the output of their product.

![Figure 1. Students’ project work on IoT system for smart living for people with different needs and pet owners.](image)

In the project, the students create a high-effective and low-cost smart home especially for people with visual disabilities or hearing disabilities or pet owners by using Internet of Things (IoT) technology. The smart home not only use various sensors to provide real-time reactions to users in 4 main aspects including clothing, food, shelter or travelling, but also use web server to store the collected data, provide data statistics and support some data analysis. The students use DHT11 Temperature Sensor for measuring temperature and humidity, pulse sensor for health checking, smoke detector for home safety, RFID via NFC for home security and robot car for pet caring. The smart home not only make the life of people with disabilities better, but also help pet owners to take care their pets when their pets staying at home alone.
Discussion

For critical evaluation, the students reported the problems and solutions in their project:

Problem 1: Sensor does not work

• **Problem:** When we want to try programming on the DHT11 sensor, the sensor cannot display the detected output. We try to search on the Internet and found that when the sensor does not work, it will show us some error messages on Arduino IDE software (as shown in Figure 2).

• **Solution:** We had tried to contact our sales in Taobao online shop and tell them our problem on the sensor, they have sent a new DHT11 for us to replace the sensor with problems.

Figure 2. The screen capture of DHT11 sensor error when the sensor does not work properly.

Problem 2: Modules inside robot car are not compatible

• **Problem:** When I test the robot car, I find a problem I need to solve. Each sensor has its own set of commands, some commands and modules are not compatible. It will affect the functionality of Robot Car.

• **Solution:** Switch to use other module that has same function and also find solutions online.

Problem 3: Lack of space inside robot car

• **Problem:** In the later stage of our project, we want to add other sensors in order to provide more features for our target user, but we find that there is not enough space inside robot car to expand.

• **Solution:**

After discussing with other experts on the Internet, we know that the installation of additional floor is feasible without affecting the normal operation of Robot Car.

Problem 4: Lack of experience on setting RFID security door

• **Software Problem:** As we were not very skilled at connecting circuits, we spent a lot of time on the wiring together in order to have a better understanding of the circuit part. Besides, the design and reality are biased. We found some errors returned when we entered the code, such as the LED lamp losing reaction. Also, it cannot detect the blue tag successfully (as shown in Figure 3).

• **Software Solution:** With these problems, we will take other ways to solve the problem. For example: ask the teacher to solve Arduino problems or view Arduino category books. On the other hand, we will find relevant information on the website and also online teaching materials (such as educational video in YouTube) to solve the current problem.

• **Hardware Problem:** When we use Arduino for the first time, we insert the wrong line situation. Therefore, some hardware did not respond. Also, there is damage in the mini-motherboard, which leads to the entire system not be fully functioned (as shown in Figure 4).
Hardware Solution:
We tried to contact the seller and asked whether there are any damages to the micro-motherboard and negotiate with the seller to replace a new miniature motherboard to solve the problem. Besides, we further explore some other technical problems and the causes to the problem with the seller. By watching the educational videos many times, we can learn the right installation process step by step clearly. It is very convenient for us to learn because we can watch the online video at anytime, anywhere. We can choose the language that we are the most familiar with. It strongly motivates us to know more about the skills involved in the installation process. The most important thing is that the basic concept we learnt before in classroom helps us to understand the technical terms used in the videos and the supervisor’s guidance helps us to do things in the right way too.

Problem 5: Sensors not having reaction

Problem:
In the testing environment, sensors do not have immediate reaction. After 1 to 2 minutes, sensor result values have very small changes only, which cannot cause the buzzer to activate.

Solution:
After research and investigation, we find out that the cause of the problem is sensor is not sensitive enough. After learning from the online video about how to train the sensors, this problem has been solved.

Conclusions
This study shows that Design Thinking Model can help out students to do hands-on project, and also online video is an effective way to help students in learning hands-on skill outside classroom. By implementing the skills in real projects, students can integrate their technical concepts into real scenario.

Our future work is to study what factors affects the degree of attractiveness of an online education videos.

References


Progress of Visualization of Learning Outcomes with Competence -
Annual Report 2017

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Abstract

The National Institute of Technology, Anan College (NIT, Anan College) was selected for the Acceleration Program for University Education Rebuilding subsidies in 2014 by the Ministry of Education, Culture, Sports, Science and Technology. Many institutions of higher education in Japan applied for this project, and after strict evaluation, the effort of NIT, Anan College was highly evaluated. Especially, in Theme II (Visualization of Learning Outcome), NIT, Anan College was the unique College of Technology designated. Our college promotes an environment where students can study thoroughly and unsupervised. Of great benefit for students is the evaluation of academic results by the monitoring their daily learning processes, encouraging them to make a habit of studying voluntarily, visualizing their competence as acceptable members of society and fully utilizing their own capacity for career design.

The core of the approach consists of four programs: (1) Ensure the time spent learning is accumulated in the Learning Portfolio. (2) Evaluation of creative skills. (3) Implementation of student surveys to evaluate the actual learning situation. (4) Creation of an Academic Portfolio for instructors focused on improving education and developing their skills. We describe these challenges in FY2015, FY2016 and FY2017. All students set goals in three categories consisting of career, academic study and co-curricular activities at the beginning of the fiscal year and then evaluated themselves at both the middle and end of the fiscal year. Trial evaluations of competency in about forty regular curriculums throughout the first semester of FY2017 using a newly developed rubric was conducted. The student surveys confirmed that the study hours outside the classroom increased gradually over several years. One of the reasons is the use of the Learning Management System utilized by faculty since its introduction at the college-wide level in FY2014. Our college hosts a workshop for creating Academic Portfolios as a part of faculty development and we also host a workshop with reduced hours to ensure the convenience of faculty attendance.

In this paper, the detailed achievements and results addressed up to now are described, and the future plan of competence development within the visualization of learning outcomes is reported.

Keywords: Visualization of Learning Outcome, Management of Teaching and Learning, Career Design, Learning Portfolio, Competence, Student Survey, Academic Portfolio

Introduction

The August, 2012 report released by the Central Council for Education, emphasized quality assurance. The keywords listed were: active learning and visualization of learning outcomes. The second Basic Plan for Promoting Education released by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) was approved in a Cabinet meeting in June, 2013. One of the basic policies is to promote university reform to increase the overall study hours of students. They have to acquire skills to continue studying by themselves throughout their career. Therefore, we ought to improve our educational methods in order to support students in achieving their goals.

In 2014, MEXT selected our educational program as the Acceleration Program for University Education Rebuilding (AP). Our program is classified in Theme II which is aimed at visualizing learning outcomes and is characterised by focusing on competence. We were able to gain insight into the educational improvement system based on the proven worth of the activities.

Proven performance

Creating a teaching portfolio within the National Colleges of Technology has prevailed more-so than at universities and colleges. Twenty workshops have been held both on and off campus with cooperation...
between the Colleges of Technology so far. More than 80% of NIT, Anan College faculty members created portfolios.

NIT, Anan College has implemented the use of IR for teaching and learning since 2010. We have compiled surveys targeted at first grade students as well as student body surveys and graduation surveys, all of which share the importance and the methods of using IR in professional development workshops for faculty, and in which almost all faculty participate.

Using these means, NIT, Anan College has a fundamental commitment to improve teaching and learning. Quality assurance and teaching improvement using IR and TP at Anan College started from 2010.

Reconstructed program of visualization of learning outcomes

The overview of the reconstructed AP program at NIT, Anan College is shown in Figure 1. Our aim is to prepare educational circumstances which provide students the ability to study by themselves. Then we improve the educational management with an emphasis on the knowledge students have to visualize the learning outcomes. We think it is better to put more value on the learning process in order to achieve an attainable target for students. The cloud-based Learning Management System (LMS) is one of the solutions. It can offer e-learning, so students are able to study anywhere at any time. All students can access the LMS from anywhere that can connect to a network. Faculty can take care to maintain a connection with students through the network at anytime and anywhere.

Students have to learn practical expertise necessary in society. Recently, the competency to adapt socially and to get through life is also required. Therefore, we prepare the visualization of competence which allows students to get through their student life in our college and supports their career formation. Students acquire competence of various types throughout their student life in our college including curriculum and cocurricular activities. Since active learning-style classes have allowed students to gain competence easily, we added the promotion of active learning in class in this program from FY2017.

On-going activities

Our program started from the second semester in 2014. The office for Excellence in Teaching and Learning was newly-organised to carry out our program. At first, we prepared the LMS as educational infrastructure and carried out a survey to understand the trend of competence for all current students using LMS. Actually, 97% of current students responded. Homeroom instructors returned the result report sheets to each student at a meeting and the students received the same result as a PDF file on LMS. After the students recognized their own competence, they set specific goals for achievement within the year using learning portfolios on LMS. We expect students to set goals by reflecting on themselves. Homeroom instructors have regular meetings to help them achieve success. We expect students to have a positive attitude toward achieving their goals and to make an effort toward achieving their aims. In order to realize our vision, we allow students to begin with a set of goals and to analyze their progress at the end of the fiscal year.

The use of LMS in our college has increased rapidly. We started to use LMS at a college-wide level from April, 2015. The ratio of faculty use was 76% and the ratio of lecture use was 47% in September, 2017. The one for lectures at the end of FY2014 was less than 10%. We laid the foundation for active learning using ICT education.

We determined six upper-level skills using the company survey regarding the competency in the Model Core Curriculum of National Institute of Technology, because it is difficult to develop, and to evaluate many skills at a time. These six skills are “communication”, “group skill”, “independence”, “sense of responsibility”, “discovering problems”, “logical thinking”. We also created a rubric for each skill and used them to evaluate student skills. In the trial evaluation, self-evaluation and mutual evaluation of students, faculty evaluation were carried out. From these results, self-evaluation of students is found to be effective as a real sustainable evaluation while avoiding an excessive burden increase.

We also revised the evaluation rubric we developed. In addition, students self-evaluated the level of competency acquired from regular lessons, cocurricular activities, and other activities using this rubric at the end of FY2017. The results and feedback were shown to each student via LMS as a radar chart shown in Fig. 2.

We studied the improvement of student competency by self-evaluation before and after the "cooperative education," which is a PBL type compulsory subject. Students cooperated in a group composed of different course students of the 4th grade and we implemented the new curriculum along with the reorganization for one department and the new course system in FY2014.

Results and Discussion

![Figure 1 Overview of AP program at NIT, Anan College. There are four important approaches. We added the promotion of active learning in class in this program from FY2017.](image-url)
After finishing the cooperative education, we asked the students about the feeling of improving related to competences.

The results of each skill show that there are many students who provided an overall evaluation of a feeling of improvement. For all skills, we estimate that more than 80% of students have evaluated "successful", and they can infer through the practical training that they were able to capture the opportunities for success using competences.

From the results of each skill, it turns out that there are many students who make an overall evaluation of feeling of improvement. For all skills, we estimate that more than 85% of students have evaluated "improve", and they can infer through the practical training that they were able to capture the opportunities to improve using competences.
The results of self-evaluation of competences are shown before and after collaborative education. The results of each skill show that there were many students who selected that "They could do it completely" or "They could do it better than they thought". It can be seen that the ratio of negative evaluation decreases as an overall trend, and each cluster is shifting to an upper cluster. Although there is an individual difference in the absolute evaluation which should be considered, the results in which the feeling of improvement individually was realized for each student were obtained. On the other hand, there is little change in the proportion of students who answered "not much" or "not at all". For students who have difficulty participating in practical training, which requires advanced communication skills such as cooperative education, it became clear that it is necessary to implement some special support.

Based on the results of the student survey regarding the method of implementing cooperative education, 70% or more of the students have positive opinions concerning cooperation with other courses, and it is considered that training on a mixed team is effective.

Conclusions

The students self-evaluated their level of competency acquired from regular lessons, cocurricular activities, and other activities using the rubric at the end of FY2017. The results and feedback were shown to each student via LMS as a radar chart. In the future, we plan to continue checking their strengths, weaknesses and improvement levels while adding additional radar charts.

Prior to the start of the project, neither faculty members nor students were conscious of competency acquisition, development and visualization, but they gradually became conscious of it through using the rubric. It can be expected that this kind of change in the atmosphere will be accelerated secondarily as an improvement of new lessons and efforts toward cocurricular activities.

Acknowledgements

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References

DEVELOPING COMPETENCIES THROUGH CO+WORK AND TOBITATE PROJECTS

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Abstract

The Co+work course, which started in 2016, aimed to cultivate competencies in autonomy, cooperation, and creativity through the interaction of students from the different fields and classifications as they tackled a shared project. The name “Co+work” is derived from the thought of having a need to create something by cooperating in practice. We have chosen to use “co-” for communication, consensus, commitment, cooperation, and collaboration. Similar exercises have been implemented in many universities and NIT colleges, but ours is unique in that the students consider and decide their own topics to tackle rather than the teachers deciding and proposing what projects to do for them.

Another program that builds competencies is the “Tobitate! (Leap for Tomorrow) Study Abroad Initiative.” Tobitate is a scholarship program provided by Japan’s Ministry of Education, Culture, Sports, Science, and Technology (MEXT) that aims to help eager and capable Japanese youth to take their first steps toward studying abroad. In NIT-Akashi College, seven students in 2015, twelve students in 2016, two students in 2017 and five students in 2018 received Tobitate scholarships and studied in schools, did voluntary work in NGOs, or worked in companies for one month.

This paper describes how students developed their competencies through Co+work and Tobitate and analyses their results on the Progress Reports on Generic Skills (PROG) Test. The PROG Test consists of 33 specific characteristics, 9 subcategories, and 3 main categories in competency. The change in competencies and the relationship between the students’ grades and experience are analysed. The PROG Test was conducted on 26th January 2016 before Co+work was implemented, then on 17th January 2017 and on 18th January 2018.

As a result of these projects, the social effect of seniority, the temporary decline in competence due to difficult experiences and the subsequent growth, and the growth difference seen in certain types of competencies became clear. As Co+work has been carried out for two years and Tobitate for three years, the competencies of NIT-Akashi College (NITAC) students have become significantly noteworthy in comparison to that at other NIT colleges and Japanese universities.

Keywords: PBL, grades, PROG, Co+work, Tobitate, competency, experiment, seniority

Introduction

This paper is a continuation of a report on a three-year project. In order to bring the readers up to date on how the project started and where it is going, much of the Introduction along with a portion of the Methods section, and Tables 1 and 2 have been re-printed from last year’s publication (Hiraishi, et al., 2017).

We are facing rapid social changes due to the recent circumstances in which globalization generates more people who have a wider and more diverse sense of values and in which advancements in ICT has made it easier to acquire information. This urges people to refresh and renew their own abilities constantly along with these social changes. Thus, an ability to keep learning actively has become much more significant now than ever before. We are also facing complicated problems that involve multidisciplinary issues which require an ability to cooperate with professionals from other fields to tackle these complexities. Rieckmann (2012) mentioned that universities may play very different roles in the future and could more or less be able to cope with global change and the complexity and uncertainty linked to these changes. Furthermore, the necessity of regular subjects for the purpose of nurturing generic skills in Japanese undergraduate education are advocated by Yoshihara (2007).

Unfortunately, in Japan, due to the declining birth rate and a growing tendency to have “play alone” single-child families, today’s youth have fewer opportunities to interact in groups. At the same time, passive education rather than active learning has remained mainstream in Japan. These circumstances make it difficult to cultivate competencies in collaboration, autonomy, and creativity.

In order to solve these problems, NITAC introduced Co+work to develop autonomy, collaboration, and problem-solving skills through challenging team experiments for creating goods or services that would make life happier for people. Hiraishi, et al. (2017) reported the educational effects of the first year of Co+work at ISATE 2017, which included the following insights:

1) In the past, in Kosen education there was no obvious competency growth.
2) Competencies of 3rd year and 4th year students obviously grew by the implementation of Co+work.
3) Competencies in problem-solving improved through Co+work because students set their own themes.
4) It is important to develop good relationships through team building in the initial stage.
5) The setting of themes that everyone can participate in is important for maintaining motivation to complete activities.

Methods
The National Institute of Technology, Akashi College (NITAC) introduced Co+work to develop autonomy, collaboration, and problem-solving skills through experiments for creating goods or services that would make life happier in spring 2016. Table 1 shows the schedule of the Co+work course, which took place in 90-minute sessions once per week.

Table 2 shows the competency structure used for the Progress Reports on Generic Skills Test (PROG Test) in the PROG Hakusho Project (2016). The PROG test was conducted on 26th January 2016 before Co+work was implemented and on 17th January 2017 and on 10th January 2018 after Co+work was completed. The students of the 2nd year, 3rd year, and 4th year were examined through their PROG test results. In accordance with the PROG Hakusho Project (2016), the test consists of the following three types of computer adaptive questions:

1) The bilateral selection format which presents two ambiguous answer choices positioned side-by-side with hidden values and which forces the quick selection of one’s first impression of the answer which they can relate to more closely.
2) The scenario assumption format (short sentence) which proposes answers that are generally considered to be positive for conflicting situations that anyone may be experiencing and asks how often the subjects have reacted in a certain way.
3) The scenario assumption format (long sentence) which proposes answers that are generally

<table>
<thead>
<tr>
<th>Week</th>
<th>Overview</th>
</tr>
</thead>
<tbody>
<tr>
<td>1&lt;sup&gt;st&lt;/sup&gt;</td>
<td>Guidance and team making in the gym</td>
</tr>
<tr>
<td>2&lt;sup&gt;nd&lt;/sup&gt;</td>
<td>Ice breakers and brainstorming activities with teammates in the gym</td>
</tr>
<tr>
<td>3&lt;sup&gt;rd&lt;/sup&gt; – 7&lt;sup&gt;th&lt;/sup&gt;</td>
<td>Theme setting by each team</td>
</tr>
<tr>
<td>8&lt;sup&gt;th&lt;/sup&gt; – 13&lt;sup&gt;th&lt;/sup&gt;</td>
<td>Project progression by each team</td>
</tr>
<tr>
<td>14&lt;sup&gt;th&lt;/sup&gt;</td>
<td>Intermediate Presentations Four teams present their projects in one room. Seven minutes for presentations and 8 minutes for questions and comments.</td>
</tr>
<tr>
<td>15&lt;sup&gt;th&lt;/sup&gt;</td>
<td>Reflection by each team</td>
</tr>
<tr>
<td>16&lt;sup&gt;th&lt;/sup&gt;</td>
<td>Intermediate Guidance</td>
</tr>
<tr>
<td>17&lt;sup&gt;th&lt;/sup&gt; – 28&lt;sup&gt;th&lt;/sup&gt;</td>
<td>Project progression by each team</td>
</tr>
<tr>
<td>29&lt;sup&gt;th&lt;/sup&gt;</td>
<td>Final Presentations Poster session in the gym</td>
</tr>
<tr>
<td>30&lt;sup&gt;th&lt;/sup&gt;</td>
<td>Reflection by each team</td>
</tr>
</tbody>
</table>

Reprinted (Hiraishi, et al., 2017).
considered to be positive in response to conflicting situations that can occur in work places and forces the selection of what actions to take in light of the subject's experience.

Table 3 shows the number of Tobitate scholarship students and their destinations each year. The total number, 26, is the second largest nationwide in the Tobitate Scholarship program for high school students. The specific characteristics and growth of the Tobitate scholarship students are clarified by the PROG test.

### Table 3 Tobitate Scholarship of NITAC

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of students</th>
<th>Destinations</th>
</tr>
</thead>
<tbody>
<tr>
<td>2018</td>
<td>5</td>
<td>Estonia, Garman, Philippines, USA (2)</td>
</tr>
<tr>
<td>2017</td>
<td>2</td>
<td>Italy, Indonesia</td>
</tr>
<tr>
<td>2016</td>
<td>12</td>
<td>Australia, Belarus, Costa-Rica, Garman, Nepal, New-Zealand, Philippines, Senegal, Spain, Taiwan, USA (2)</td>
</tr>
<tr>
<td>2015</td>
<td>7</td>
<td>Australia, Brazil, UK, Sri Lanka (2), Vietnam,</td>
</tr>
</tbody>
</table>

**Results and Discussion**

There were no obvious differences in competency scores between other NIT colleges and among 2nd, 3rd, and 4th year students in 2016 before introducing Co+work as shown in Figure 1. The numbers of participants from other NIT colleges contributing to the data were 1,539 second year students, 1,243 third year students, and 2,114 of fourth year students. The competency of 3rd year and 4th year students increased, however the competency of the 2nd year students increased only a small amount after a year of lessons in 2017. Again, in 2018, the competency of 2nd year students was low. The change in competency between 1st and 2nd year of the same students could not be compared, as the PROG test was deemed too difficult for 1st year students, hence they did not take it. In a comparison between competencies of 2nd year students in 2017 and 2018, the autonomy and problem-solving skills of students in 2018 were found to be much lower, as shown in Figure 2. One reason for this is considered to be that 2nd year students had difficulty committing to the project because of the large competency differences between the 2nd year students and 3rd and 4th year students who had prior experience with Co+work. However, the same students who became 3rd year students in 2018 had significant increases in competency scores in their second year of the project. By mixing different classes of students, those with seniority generally felt a sense of responsibility for taking on leadership roles. In addition, since it can be thought that the younger students can see their own growth model, this observation was necessary for the effect of the mixed grade-levels to be realized.
Figure 3  Specific competencies of students from 2nd year in 2016 to 3rd year in 2017 to 4th year in 2018
(Averages shown with standard errors indicated. Specific characteristics marked with “●” showed clear improvements in 3rd year to 4th year, and those marked with “◎” showed clear improvements in 2nd year to 3rd year.)

Figure 4  Specific competencies of students from 2nd year in 2017 to 3rd year in 2018
(Averages shown with standard errors indicated. Specific characteristics marked with “●” showed clear improvements)
Figure 5 compares specific characteristics of Tobitate scholarship students to all 2nd year students in 2017. Tobitate scholarship students saw significantly high scores in most of the competency categories, except “stress tolerance,” “cause pursuit,” “plan evaluation,” “risk analysis,” and “interpersonal interest, sympathy, and acceptance.” It can be said that Tobitate scholarship students are typically those who have comprehensively high competency and are strongly independent but are not deep thinkers.

Figure 6 shows the competency scores from Tobitate scholarship students and other students with respect to each grade. The competency scores of the Tobitate scholarship students are obviously higher than that of the other students. However, the competency scores of the Tobitate scholarship students slightly decreased from 5.2 in the 2nd year to 5.1 in their 3rd year, and the standard error increased as well. Then, their scores shot up again in their fourth year. This shows the tendency for Tobitate scholarship students to slightly lose their confidence during or just after their tough work they have done alone and overseas followed by the realization in the following year that they have learned and grown from the experience.

Looking at subsequent growth from 2nd year to 4th year of the Tobitate Scholarship students in Figure 7, the Tobitate Scholarship students developed “cause pursuit,” “plan evaluation,” and “risk analysis.” However, “interpersonal interest, sympathy, and acceptance” and “stress tolerance” were not changed. And, “making good behavior habitual” was significantly decreased. It was assumed that the students realized their abilities were not enough for the project whilst abroad. They then recognized that effort was necessary, but their daily actions did not demonstrate the level of effort necessary to reach their personal goals.

**Conclusions and implications**

The following conclusions can be made from PROG test results with respect to the continued implementation of Co+work for 2 years and the competencies of Tobitate scholarship students:

1. Competencies were almost the same between other NIT Colleges and NIT, Akashi College before the implementation of Co+work.
2. Competencies of 3rd year and 4th year students obviously grew by the implementation of Co+work.
3. Competency scores of 2nd year students did not grow significantly during the first time they experienced Co+work; however, they did grow in
the next year when, as 3rd year students, they already had a full year of Co+work experience.

4) The chain of seniority within the Co+work project teams affected the results of competency growth.

5) The competencies of Tobitate Scholarship students were higher than other students.

6) One of the subcategories, “Sustaining action,” which includes, “Proactive behavior,” “Accomplishment,” and “Making good behavior habitual” should be the next target for developing our students competencies.

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THE EFFECT OF CHEMISTRY CARD GAME ON STUDENTS’ LEARNING MOTIVATION AND ACADEMIC ACHIEVEMENT

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Abstract

A chemistry card game was designed to encourage students of different learning abilities to communicate, cooperate and collaborate in the classroom. Through this project, we hope to address the question on whether the card game is effective in enhancing students’ learning motivation and academic achievement. All the four classes of students (N=86) from Chemical Technology program participated in this study. During the tutorial lesson, class 1 and class 2 completed the pen-and-paper worksheet, followed by playing the game. Class 3 and class 4 played the game before doing the worksheet. Pre- and post-tests, as well as a set of questionnaire were administered to capture students’ learning experience on the game and worksheet. It was found that students improved their test score by 41% and 45% when they only did tutorial using pen-and-paper worksheet and game respectively. However, the combination of worksheet and game significantly improved the test score by an average of 74%. This indicates that although the worksheet and game are effective to improve students’ academic result by their own, it would be best if both approaches were used together to further improve the students’ learning. Based on the survey results, all students believed that both the worksheet and game helped them learn the topic better. However, only 68% of them enjoyed doing the worksheet. 29% of them even felt that it was a boring activity. On the other hand, all the students (100%) perceived that the card game was an interesting way to learn, and they enjoyed playing the game as they could interact and bond with their classmates. In conclusion, the Chemistry card game provides an affective learning environment for students to learn. This research outcome is encouraging for educators in the institutes of higher learning (IHLs) to design and adopt the in-class educational group games more frequently and enthusiastically. The components of excitement and entertainment while playing the game in a group appeal the new millennial learners. This study helps to garner more support from schools’ management and parents on the implementation of the in-class educational group games to increase students’ motivation and academic achievement.

Keywords: Education Research, Educational Group Games, Learning Motivation, Chemistry, First-Year Students

Introduction

Traditional learning method where students learn through listening and interpreting the content delivered by the teacher passively is still prevalent in many higher education institutes as it is a convenient way to teach and introduce the basic concepts (Van Eynde & Spencer, 1988; Smith & Valentine, 2012). However, students are not engaged in the passive-learning classroom. Although several active learning activities such as team-based learning, problem-based learning, small group discussion and presentation had been attempted, they are only able to engage a small group of students who are vocal and highly intellectual. Majority of the students find the activities boring, challenging and daunting. Hence, there is a need to make the lessons more lively and less pressurized, yet can still achieve the students’ learning outcome and enhance their academic achievement.

Educational group game (EGG) may provide a good solution. In fact, psychologists have long acknowledged the importance of play in physical, social, emotional and cognitive development and learning. Piaget (1962) described that play is a way for children to unify experiences, knowledge and understanding. Vygotsky (1967) proposed that when a learner is playing with an adult or a more capable peer, he or she is likely to succeed at things that are beyond his or her current ability. Bruner et al. (1976) found that play reduces stress, and believed that it enables children to focus and established their own learning experience goals, thus enhancing learning attainment.

Although majority of Singapore school teachers believe that games can lead to better student learning outcomes, they rarely incorporated games in teaching. The main obstacles include not only the time and effort spent in the game development and game delivery, but also the school support and parents’ reactions towards the game-based learning (Koh et al., 2012). Therefore, the aims of this research are: (1) to design an educational group game that has fun, motivating and cognitive elements, to encourage students of different learning abilities to communicate, cooperate or collaborate when they play the game; (2) to find out whether the game can help enhance students’ learning motivation and academic
achievement. Successful implementation of that in-class educational group game in the local context may change the school and parents’ perception of game-based learning, and inspires more teachers to adopt and use games more frequently in the classrooms.

Materials and Methods

Card Design & Game Activity

The game cards were designed to be played in groups of 4-5 students. Each group was given one set of 40 cards. Each card includes four information of an organic molecule, which are the total number of carbons, structure, name, and the functional group that the chemical molecule has. However, every card has its own missing information (Figure 1). Students have to work together to furnish the card details during the tutorial lesson. After that, they used the cards to play game.

Figure 1. An example of a game card which has a missing information of: (a) the total number of carbons in the molecule, (b) structure, (c) name of the molecule.

The 40 different cards were also classified into four suits based on the functional groups and priority system in the chemistry nomenclature (Figure 2). This is similar to the poker cards, which also have four suits, namely diamond, club, heart and spade. However, in this chemistry game set, each suit only consists of 10 cards, with molecules consisting of total carbon number that ranges from 3-12.

Figure 2. (Left) Four suits of chemistry cards based on functional group and nomenclature priority. (Right) The “diamond” suit that consists of 10 cards with different number of carbon atoms in the molecules.

The game mechanic is similar to that of the Big-Two game, which is popular and already known to most of the students. Starting player is the one that holds smallest ranking card. One card is played at one time. The next player can either play out the higher-ranking card or say “pass”. If a player plays out a card, and all other players say “pass”, then the player can restart the round by playing out a card that is at low rank. The game ends when a player runs out of cards. It was suggested that a successful educational group game should have a simple game mechanic that merges the game and pedagogical elements to create a fun and engaging learning experience (Triboni & Weber, 2018). Indeed, adopting an existing and famous game mechanic had cut down the time used to explain the game. Students could easily pick-up and play the game in the shortest time.

Research Design

All first year students (N=86) from Chemical Technology program had given consent and participated in this study. Quasi-experiment was employed as there are four pre-existing tutorial classes. Figure 3 provides an overview of the research design.

Figure 3. The research design to study the effectiveness of the card game.

During the two-hour tutorial lesson, all students did the pre-test, went through the traditional pen-and-paper worksheet, played the game activity, attempted the post-test and completed questionnaires. This was to ensure fairness across the four groups so that no student would be on disadvantage in terms of missing out the content of the lesson. However, the sequence of the content delivery was different. Through this research design, we can understand: (1) from group 1 data - the effectiveness of pen-and-paper worksheet, (2) from group 3 data - the effectiveness of the game, and (3) from groups 2 and 4 data - whether the combination of the two activities can better enhance students’ academic achievement.

In addition, surveys were conducted at the end of each activity to understand student perceptions on both the worksheet and game. The questionnaires were adapted from a validated instrument, known as the Intrinsic Motivational Inventory (IMI). It is a multi-dimensional measurement device created by Ryan and Deci (2000) to assess the participants’ subjective experience related to a target activity.

Results and Discussion

Students’ academic achievement was measured by comparing the pre- and post-test scores. Table 1 shows the mean scores and standard deviations (SD) of the test results for all the four groups of students. The pre-test scores are in the marginal range from 4.4 marks to 6.4 marks (average = 5.4 marks, grade D), implying that students’ prior knowledge after the mass lecture and before the tutorial is just in grudging acceptance. The
post-test scores range from 6.9 marks to 9.3 marks (average = 8.4 marks, grade A), showing that the activity(ies) has/have enhanced the students’ understanding of the lecture topic.

Table 1. The mean scores and standard deviations (SD) of the test results in the four groups of students. The base mark of the tests is 10 marks.

<table>
<thead>
<tr>
<th></th>
<th>Grp 1</th>
<th>Grp 2</th>
<th>Grp 3</th>
<th>Grp 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-test Mean:</td>
<td>4.9</td>
<td>4.4</td>
<td>5.8</td>
<td>6.4</td>
</tr>
<tr>
<td>SD:</td>
<td>1.8</td>
<td>1.3</td>
<td>2.1</td>
<td>1.7</td>
</tr>
<tr>
<td>Post-test Mean:</td>
<td>6.9</td>
<td>8.9</td>
<td>8.4</td>
<td>9.3</td>
</tr>
<tr>
<td>SD:</td>
<td>1.8</td>
<td>1.5</td>
<td>1.8</td>
<td>1.2</td>
</tr>
</tbody>
</table>

Figure 4 shows the test score results in chart form. Students’ test scores improved by 2.0 marks (41%) and 2.6 marks (45%) when they do worksheet and game respectively. This implies that the game activity is as effective as the pen-and-paper worksheet in improving students’ learning. The combination of worksheet and game is even better. As reflected in groups 2 and 4 data, the post-test mean scores were pulled up to about 9 out of 10 marks. This result echoes with the finding by two meta-analyses of the effectiveness of educational computer games done by Sitzman (2011) and Wouters et al. (2013). Both of the meta-analyses concluded that educational game is more effective when they are supplemented with other instructional method(s) rather than when it is used alone.

Students actively participated by talking enthusiastically about the chemistry cards that they were holding.

Table 2. The mean scores and standard deviations (SD) of students’ motivations and attributes towards the worksheet and game activities.

<table>
<thead>
<tr>
<th></th>
<th>Worksheet</th>
<th>Game</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>Motivation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interest&lt;sup&gt;+&lt;/sup&gt;*</td>
<td>20.10</td>
<td>4.07</td>
</tr>
<tr>
<td>Direct Performance*</td>
<td>13.33</td>
<td>2.23</td>
</tr>
<tr>
<td>Indirect Performance</td>
<td>13.48</td>
<td>2.93</td>
</tr>
<tr>
<td>Attributes</td>
<td></td>
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<tr>
<td>Value</td>
<td>15.60</td>
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<tr>
<td>Perceived Choice*</td>
<td>13.83</td>
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<td>Perceived Competency</td>
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<td>2.07</td>
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<td>Effort</td>
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<td>1.88</td>
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<td>Pressure</td>
<td>9.63</td>
<td>2.57</td>
</tr>
<tr>
<td>Relatedness</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

In addition, there was a significant reduction in the direct performance-salient incentive towards the game. This means that students did not think that the game could help them improve in their grade. However, the pre- and post-test has shown that the game is effective in improving the students’ grade by 45%. This shows that the game has enabled students to master the skill and knowledge subconsciously, and without realising it as an actual learning process. Such outcome is desirable and especially pleasant to educators as game can potentially help to overcome the students’ trepidation of learning difficult topics.

There was an insignificant drop in the indirect performance-salient incentive towards the game as compared to that of worksheet (p=0.035). Further analysis has shown that students wanted to do the worksheet and play the game well intrinsically and not because they wanted to gain recognition by teacher or among the peers. It was also noted that during the game activity, academically good students were teaching the weak ones voluntarily, and the weak students became more engaged to furnish the card details to play the game. As such, the card game has indeed encouraged students of different learning abilities to communicate, cooperate or collaborate. It is good to have these soft skills to be cultivated during the lessons as they are essential for students’ holistic development and have great impact on their future job performance (Zhang & Venkatesh, 2013).
and game). Generally, students felt that both doing the worksheet and playing the game have helped them better understand the lecture topic (Value Attribute). They believed that they were quite competent when doing the activities, and were satisfied with their performance (Perceived Competent Attribute). They did not put in much effort in completing the activities (Effort Attribute), and did not feel tense/pressured/anxious when doing the activities (Pressure Attribute). However, there was a significant increment in the attribute on perceived choice towards the game. Students did not feel like they were forced to play the game. This implies that game provides a more preferable learning mode for students, as compared to that of the pen-and-paper worksheet.

Next is the attribute on relatedness, which assesses students’ perception of personal connection with their peers when doing the activity. No data was collected for the worksheet as majority of the students did the worksheet individually, although they were encouraged to discuss the tutorial worksheet among themselves. On the other hand, there was a positive response that students felt connected and close with their group-mates when they furnished the game cards and played the game together (M=16.42 with the base mark of 20, SD=2.39). This result was further supported by the open-ended questions in the survey form. Many students have given the feedback that they enjoyed the game activity as it helped them to train their thinking, improved the communication skill and promoted teamwork.

Conclusions

A simple and low-cost Chemistry card game was developed and tested in four classes of first year diploma students from Chemical Technology program. Study shows that the game provides an affective learning environment for students to learn in a playful and interactive way. The components of excitement and entertainment while playing the game appeal the new millennial learners. The effectiveness of the game as a complementary mechanism to maximize students’ learning was also demonstrated in this study. Such result is encouraging for educators in the institutes of higher learning to design and adopt in-class educational group games more frequently and enthusiastically. Such result is encouraging for educators in the institutes of higher learning to design and adopt in-class educational group games more frequently and enthusiastically. In addition, the findings also provide concrete evidence to show to the school management and parents that in-class educational group game does motivate students to learn and improve the their academic result. Hence, more support can be sought and more resources may be allocated to develop more interesting in-class educational group games in the future.

Acknowledgements

The authors would like to thank J. Fu and G.W. Sim for their invaluable help with testing the game, and involvement in some stages of this project. We are also extremely grateful to all the students and parents who fully agreed (or allowed the child) to participate in this research project. This work was supported by MOE-TRF (Ministry of Education - Tertiary Education Research Fund), Singapore.

References


THE DEVELOPMENT OF 21ST CENTURY COMPETENCES BASED ON THE IMPLEMENTATION OF ACTIVE LEARNING IN THE TEACHING OF EXPERIMENTAL SCIENCES

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Abstract

In the modern society, students must acquire skills that are very different from the skills required 20 years ago. Nowadays, students should show skills that can be classified in three groups: foundational literates (scientific, technological, financial, cultural and civic literacy), competencies (critical thinking, problem-solving, creativity, collaboration and communication) and character qualities (curiosity, initiative, adaptability, leadership, cultural and social awareness). It is necessary that the role of teachers be oriented to the design of processes that promote the construction of knowledge to develop the 21st century skills. These skills should be an integral part of lesson planning and assessment in the teaching-learning process. In this sense, teachers need to combine didactic strategies and technological tools to achieve the development of 21st century skills. In this project, we studied the combination the didactic strategies such as Problem based Learning (PBL)-active learning with technological tools (applets and simulators). The objective of the project was associated with the design, analysis and construction of a spaghetti bridge (open ended issue). The type of knowledge expected was conceptual, procedural and application. It is important to point that through the development of projects, students developed skills associated with access information, evaluate sources, align solution with task, assume shared responsibility, apply strategies, take a variety of roles, tolerate different viewpoints, listen actively, express ideas, learn from mistakes, know personal creative process, draw conclusions, reflect on learning, ask clarifying questions and maintain positive values. The use of free tools such as simulators and tools that support the collaborative activities and feedback process (Google Docs) represents a great opportunity to incorporate the development of 21st century skills in our classroom. It is for this reason that we must promote the integration and intensive use of these tools.

Keywords:
Active-learning, Problem based learning, Learning-tools, Learning-Environment, Teaching-strategies

Introduction

The development of the skills necessary for life in the Knowledge Society has become a priority for the educational systems of the world. The learning expectations, during this century, are associated with competences such as: creativity, innovation, critical thinking, communication, collaboration, digital and information literacy and social and personal responsibility [1]. These skills and competences are usually called 21st century skills and competencies in order to indicate that they are more related to the needs of emerging models of economic and social development than those of the last century at the service of the industrial mode of production. In this regard, the member countries of the Organization for Economic Cooperation and Development have developed joint efforts and projects to achieve these competencies. The general objectives of these projects are, on the one hand, to conceptualize and analyse from a comparative perspective the effects of new digital technologies on the cognitive development of young people as well as on their values, lifestyles and educational expectations and, on the other hand, examine the responses to the emergence of this phenomenon in terms of educational policy and practice.

For many young people, schools are the only place where skills are developed. Therefore, governments should work to identify and correctly conceptualize the set of skills and competencies required according to the educational standards that each student must be able to achieve by the end of compulsory education. For this, educational authorities should be aware that in order to be successful in this process, a double effort must be made: encourage the participation of economic and social institutions from private companies to higher education institutions. However, this whole process runs the risk of being irrelevant to schools unless this set of skills and abilities becomes the frame of reference for teachers and educational institutions [2].

Active learning is one of the teaching-learning methods that has increased its popularity in educational institutions in recent years. The path that the conventional learning process takes is invested in working under the foundations of active learning. While traditionally the information is first exposed and then its application is sought in the resolution of a problem, in the
case of active learning: first the problem is presented, then the learning needs are identified, and the necessary information is sought and finally it is returned to the problem. In the journey that the students live from the original approach of the problem to its solution, they work collaboratively in small groups, sharing in that learning experience the possibility of practicing and developing skills, of observing and reflecting on attitudes and values that in the conventional expository method could hardly be put into action. The experience of work in the small group oriented to the solution of the problem is one of the distinguishing characteristics of active learning. In these group activities the students take responsibilities and actions that are basic in their formative process. Active learning is a method that is feasible to be used by teachers in most disciplines, as a form of work that can be used in a part of their course, combined with other teaching techniques and defining learning objectives that you want to cover.

In this project we propose the integration of didactic and technological tools that allow the development of useful skills for life in our students. In order to achieve this objective, it is necessary that the role of the teacher is oriented to the design of processes that promote the construction of knowledge and the development of these skills in a joint manner.

Materials and Methods or pedagogy

The modern world demands that young people be able to collaborate, plan, think critically, make decisions, solve problems, be creative, show social responsibility and be able to handle technological tools that are not normally included in the curricula of educational institutions. In addition, students must be able to work in diverse groups in such a way that they can succeed in a globalized world and in a digital economy. To develop these skills, it is necessary that the role of the teacher is oriented to the design of processes that promote the construction of knowledge and the development of these skills together. To fulfill this objective, the combination of technological tools with strategies and didactic models is proposed. For the correct integration of these tools it is necessary that before working with the students in the sessions in the classroom, we design problems that allow covering the contents and competences of the subject. Also, it is essential that the work rules and roles of each class member be established in advance and must be shared and approved in advance by the entire group. During the planning of our subject it is important that we identify the most suitable moments to apply the problems, calculating the necessary time that the students must invest in the search of the solution to the problem.

It is important to remember that active learning is based on different theoretical currents on human learning, within which the constructivist theory has a particular presence. According to this position, the active learning is based on three basic principles:

- The understanding of a real situation arises from the interactions with the environment.
- Cognitive conflict when facing each new situation stimulates learning.
- Knowledge is developed through the recognition and acceptance of social processes and the evaluation of different individual interpretations of the same phenomenon.

Active learning includes the development of critical thinking in the same teaching-learning process, does not incorporate it as something additional, but is part of the same process of interaction to learn. We must remember that active learning seeks that the student understands and deepens adequately in the response to problems by addressing aspects of philosophical, sociological, psychological, historical, practical, etc. The structure and process of solving the problem are always open, which motivates conscious learning and systematic group work in a collaborative learning experience. In active learning students work collaboratively in teams while the teacher promotes the discussion in the working session with the group. The teacher does not become the authority of the course, but rather acts as a facilitator of the search for information. It is important to note that the objective is not focused on solving the problem. In this methodology, the problem serves as a trigger for students to cover the learning objectives of the course. Throughout the group work process, students should acquire responsibility and confidence in the work done in the group, developing the ability to give and receive criticism aimed at improving their performance and the group work process. Within the experience of active learning, students integrate their own methodology for the acquisition of knowledge and learn about their own learning process. Knowledge is introduced directly in relation to the problem and not in an isolated or fragmented way. In active learning, students can observe their progress in the development of knowledge and skills, becoming aware of their own development [3].

Once we have prepared the sessions, the next step is to lead to develop the activities in the classroom. The work session with the students involves the following sequence of steps:

Step 1. Presentation of the problem

In this stage the problem is presented in digital or printed form. At this stage it is appropriate to provide written questions to students related to the problem.

Step 2. Identify learning needs

Through collaborative work, each group will identify key points of the problem and learning needs that will lead the group to solve the problem. At this stage, hypotheses are formulated, and the recognition of the information required to verify the hypotheses is produced. It is necessary that students generate a list of topics to be studied in a group. In this stage, technological tools such as simulators, Google tools or digital search engines that allow students to solve previously identified learning needs can be integrated.
Step 3. Information learning

During this stage it is appropriate for the teacher to evaluate the progress at regular time intervals. If necessary, the teacher can interrupt the work to correct misunderstood concepts or to bring the teams to the same rhythm.

Step 4. Solution of the Problem and identification of new problems.

At this stage the teacher must connect the topics studied with the learning objectives in front of the group. Also, it is important that the professor allocate some time at the end of the session so that the whole group can present, analyze and discuss the designed solutions in order to find points of agreement or define new future problems. All stages of solving the problem are recorded in a shared document of Google tools that allows the teacher to constantly assess the process of knowledge construction and, above all, makes it possible for the teacher to make continuous feedback of the work done by the team. The support through digital tools facilitates the monitoring of the search process of solutions allowing the solution times of the problem to be covered by all the equipment.

After carrying out the activities in the classroom it is necessary that students establish their own learning plans. These plans can be focused on identifying the topics to be studied, clearly identifying the learning objectives to be covered and establishing a list of tasks for the next session. Also, students can identify functions and tasks clearly indicating their support needs in areas where they consider teacher participation important. The information required to understand the problem opens thematic of study to students, they can work independently or in small groups identifying and using all available resources for the study of these issues, it is obviously important that they share the knowledge acquired with the rest of the group.

Results and Discussion

For the incorporation of this methodology it is necessary to divide the activities designed into three stages: Before-Class Activities, During-Class Activities and After-Class Activities.

a) Before-Class Activities.

These activities should be focused on encouraging the student to acquire, review or verify the previous knowledge he has regarding the problem or case study. Basically, the activities designed at this stage should represent a first exposure to the topic under study. It is important to emphasize the relevance and the purpose of the subject and to propose the applications of the acquired knowledge. The taxonomic levels developed in this stage are essentially the first two: Remember and Understand.

b) During-Class Activities.

During the analysis of the case study it is necessary to guarantee a learning environment that encourages an increase in the motivation to learn and a deep learning of the subject under study. In addition, the role of the teacher during this stage should be focused on providing support, both individualized and collective to the students. Finally, during this stage it is important for the teacher to guide the research of the case study by encouraging a constructive discussion of the topic. The taxonomic levels at this stage are associated with Application, Analysis and Evaluation.

c) After-Class Activities.

The activities designed at this stage should be focused on building and reinforcing self-confidence, online discussion, challenging questions or projects derived from the study and case analysis. The taxonomic levels at this stage are Evaluate and Create (Figure 1).

![Image of Figure 1: Learning Environment]

Figure 1. Learning Environment.

During this project different simulations were developed using a simulator of internal forces and mechanical efforts. This simulator is based on a 2D environment where it is possible to design mechanical structures that allow us to generate, test and analyze different designs. Throughout the development of this project, students had to cover different stages of solving the problem which are defined below:

Stage 1. Outcomes & Assignment

The goal of this project was related with the design and construction of a spaghetti Bridge. The kinds of knowledge associated with this activity were conceptual, procedural and application. During this stage, students had to make their own design using their creativity. The scenario proposed for this stage implied that a company has hired the services of your consulting firm to design and build a bridge as part of the infrastructure works of a new industrial zone. The model of the bridge must be constructed using only spaghetti and glue. In this way the problem arises was of the type Open-Ended Issue.
Stages 2. Norms for Collaborative Learning

Before the realization of the project the group defined the norms for collaboration. These norms included the following aspects:

a) Assume shared responsibility.
b) Respect different viewpoints.
c) Take a variety of roles.
d) Recognize know personal creative process.
e) Maintain positive values
f) Embrace diversity and respect everyone.

Stage 3. Research

This stage implies the access, organization and assessment of information. Besides, during this stage the students developed the following activities about the project:

a) Model of the Bridge, Figure 2.

b) Determination of the load applied on the bridge and determination of the distributed areas, Figure 3.

c) Calculation of the distributed loads in the supports and determination of the internal forces applied in each element of the armor, Figure 4.

d) Determination of the elements with the lowest load and the greatest load support, Figure 5.

Stage 4. Presentation

At the end of the project the students were able to:

a) Express ideas and use multiple forms of media.
b) Evaluate evidence, justify arguments and draw conclusions.

Stage 5. Assessment

The student learned to evaluate their own work from their mistakes in order to improve the results in the future.
Conclusions

The development of this project allows to improve the performance of students in the area of natural sciences, specifically in the study of physics and mechanics. Once the methodology was introduced into learning activities, students began to improve their skills associated with critical thinking, thereby improving their ability to solve problems. Problem solving skills are one of the basic skills that students must have throughout their lives, they should be used frequently when they leave school. A better performance in the problem-solving process will indirectly impact other areas of knowledge because in solving problems, students have the possibility to think carefully and critically, to test, investigate, argue, recognize their own creative processes and value and appreciate the diversity of opinions and ways of thinking. In addition, this project made it possible to investigate in detail the mechanism through which answers to "why" or "how" questions are posed.

It is important to point that the combination of technological and didactic tools allows students to develop skills to access, organize and use information, assume shared responsibility, maintain an open mind and tolerant to different points of view, work efficiently as a team, listen actively, recognize their own processes creative, generate ideas, evaluate evidence, justify their arguments, establish conclusions, show respect among them and appreciate the richness of diversity. The development of these skills increases the motivation to learn in students and contributes to the achievement of meaningful and useful learning for life.

Finally, it is important to emphasize that through active learning students assume the responsibility of their learning, work efficiently in groups, share roles and stimulate learning skills and self-directed study; which improves their ability to obtain, analyze and organize information independently. In addition, through solving real problems, students increase their levels of understanding, allowing them to use their knowledge and skills to face any obstacle throughout their life.

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References

COLOR BALL COMMUNICATION EXPERIMENT

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Abstract
This paper suggests color ball communication intended for elementary school to college students. Recently, children tend not to play with real objects. The color ball communication can send 4000 kinds of Chinese characters by the permutations of 8 balls of 8 kinds of colors. Simultaneously, it may have students interested in LEDs, a photo sensor, a plastic optical fiber, a microcomputer board, and software for coding and decoding a message with GUI including an animation. The students inspired by an extension lecture demonstrating this material may enter the college and learn principles. The students can learn reasons why LEDs can emit light and why optical fibers can guide a light. They can also learn the method of multiplexing 4 color LED lights with modulating in orthogonal sequences, the way of analyzing the light intensities reflected by an object using a factor analysis, the way of comparing and recognizing signals. Furthermore, they can learn a forward error correcting code and comprehend the necessity of redundancy. They can learn all those experimentally. They can process the measurements on an Excel's spread sheet, and use the Python to derive eigen values and vectors. They can program an Arduino board to modulate LED lights in direct sequence spread spectrum and distinguish the color by comparing their factor vectors. The Processing software allows the personal computer interact to the microcomputer. It can show up the color ball animation and the corresponding characters. A Java application codes an input message to the color ball queues by means of the (6, 3) linear block coding. Students look for the noise source to improve the reliance. They inspect the optical arrangement, the transmitting and receiving circuit, and the mechanics for picking up at the fiber’s end. They suggest the ways of raising the communication efficiency such as increasing colors or improving the coding method. They can enjoy devising some reaction like sounds to attract users.

Keywords: Color Sensor, Direct Sequence Spread Spectrum, Eigen Values and Vectors, Factor Analysis, Forward Error Correcting Code, Plastic Optical Fiber

Introduction
Factor analysis has been widely used in areas, such as biology, psychometrics personality theories, marketing, product management, operations research and finance. Explanations of the factor analysis in textbooks are so abstract, and that prevent beginners from understanding. Many students, hopefully including readers, want to understand the factor analysis. Let’s conduct an experiment on the factor analysis.

Outline of the color ball communication
Figure 1 shows a snapshot of the students’ experiment. This device can send a message by rolling color balls. This is intended for children to arise their interest in the communication technologies. Why have the color balls changed into the message? Each color plays the role of a signal. Figure 2 shows the color reader connected to a vinyl chloride pipe through a plastic optical fiber that guides lights on a round trip for illumination and reflection. Figure 3 shows the system’s indication of a message, where each character appears after reading eight colors of the balls. Figure 4 shows the color coder, where a set of eight colors indicate a Kana or Chinese character, etc.

Figure 1. Students working on the color ball communication experiment.
Principles

How do machines recognize the color? The color should be decomposed into the elements and then be compared like the paper Chromatography shown in Figure 5. How should the ball’s color be decomposed? The elements can be estimated by analyzing the reflected lights of four LEDs colored red, green, blue, and white. Figure 6 shows the photo of the device. How can each colored light be detected separately? It is done by the modulation of Direct Sequence Spread Spectrum, DSSS. Each colored LED flashes in a different pattern. Microcomputer memorizes the sum of the four reflected lights at each time step. Figure 7 shows the way of calculating the response of the green light only.
and reflection rates? Let's standardize the detected lights. Average at 0 and the variance at 1. Standardization means the transformation to fix the length of the factor loading vector at one, and also standardize each element of the factor vector.

What's the benefit of the standardization? The correlation matrix of the detected lights tells the angles among the factor loading vectors. The elements of the correlation matrix indicate inner products among the factor loading vectors. The length of the factor loading vectors are all fixed at one, so the angles among them are determined.

The row vectors, such as \((a_{11}, a_{12}, a_{13})\), are called the factor loading vector, and the vector \((f_1, f_2, f_3)\) is called the factor vector. This standardization fixes the length of the factor loading vector at one, and also standardize each element of the factor vector.

How shall we solve these elements of emitted lights? Those can be estimated by the factor analysis. The reflected lights are denoted by \(y_1\) to \(y_4\) for the four colored LEDs, and are modeled by this matrix equation.

\[
\begin{bmatrix}
y_1 \\
y_2 \\
y_3 \\
y_4
\end{bmatrix} =
\begin{bmatrix}
c_{11} & c_{12} & c_{13} & c_{14} \\
c_{21} & c_{22} & c_{23} & c_{24} \\
c_{31} & c_{32} & c_{33} & c_{34} \\
c_{41} & c_{42} & c_{43} & c_{44}
\end{bmatrix}\begin{bmatrix} \mathbf{c}_1 \\ \mathbf{c}_2 \\ \mathbf{c}_3 \\ \mathbf{c}_4 \end{bmatrix} (1)
\]

The four colored light are respectively assumed as the sum of the products of the emitted light and the reflection rate that vary depending on the wave length as shown in Figure 8.

The row vectors, such as \((a_{11}, a_{12}, a_{13})\), are called the factor loading vector, and the vector \((f_1, f_2, f_3)\) is called the factor vector. This standardization fixes the length of the factor loading vector at one, and also standardize each element of the factor vector.

Approximating the smallest eigenvalue to 0, the following term is obtained. Here, the solutions having their angles conformed have been found. Equation (5) is the expansion of the correlation matrix, composed of the eigenvalues and the eigenvectors. These are the eigenvalues and eigenvectors of the correlation matrix. Approximating the smallest eigenvalue to 0, the following term is obtained. Here, the solutions having their angles conformed have been found.

\[
\begin{bmatrix} e_{11} & e_{21} & e_{31} & e_{41} \\
e_{12} & e_{22} & e_{32} & e_{42} \\
e_{13} & e_{23} & e_{33} & e_{43} \\
e_{14} & e_{24} & e_{34} & e_{44}
\end{bmatrix} \begin{bmatrix} \lambda_1 \\
\lambda_2 \\
\lambda_3 \\
\lambda_4
\end{bmatrix} = 0
\]

(5)

\[
R =
\begin{bmatrix}
\rho_{12} & \rho_{13} & \rho_{14} \\
\rho_{21} & \rho_{23} & \rho_{24} \\
\rho_{31} & \rho_{32} & 1 \\
\rho_{41} & \rho_{42} & \rho_{43} & 1
\end{bmatrix}
\]

(4)
Let’s rotate them to find the factor loading vectors. They have been found as Figure 9. Let’s find the factor vectors to minimize the errors. They have been found as Figure 10.

The color recognition is not always successful. The fault is supposed to be caused by chattering in the mechanics for picking up reflected lights at the fiber’s end. This lead us to another educational opportunity.

The random deviation may cause wrong recognition between the colors which are close to each other in the factor vector. So, we can predict the colors into which a color changes. Unless the chattering is strong, we can confine the number of the colors.

The (6, 3) code can become the useful code for this case as the forward error correcting (FEC) code. The six bit length code consists of three data bits and three parity check bits. If one of the digits has been wrongly received, the receiver can be aware there has happened an error and correct it.

For the (6, 3) code, the code word is represented by Equation (6) with the calculation of modulo 2 additions,

\[ c = dG \]  

(6)

where \( G \) is called the generator matrix as

\[
G = \begin{bmatrix}
1 & 0 & 0 & 1 & 0 & 1 \\
0 & 1 & 0 & 0 & 1 & 1 \\
0 & 0 & 1 & 1 & 1 & 0
\end{bmatrix}
\]

As the results, the code word \( c \) is represented for each data word \( d \) as Table 1. The Hamming distance among them keeps three bits at least, so a code received with one bit error can be corrected to the nearest code from it.

<table>
<thead>
<tr>
<th>Data Word ( d )</th>
<th>Code Word ( c )</th>
</tr>
</thead>
<tbody>
<tr>
<td>000</td>
<td>000000</td>
</tr>
<tr>
<td>001</td>
<td>001110</td>
</tr>
<tr>
<td>010</td>
<td>010011</td>
</tr>
<tr>
<td>011</td>
<td>011101</td>
</tr>
<tr>
<td>100</td>
<td>100101</td>
</tr>
<tr>
<td>101</td>
<td>101011</td>
</tr>
<tr>
<td>110</td>
<td>110110</td>
</tr>
<tr>
<td>111</td>
<td>111000</td>
</tr>
</tbody>
</table>

For the received word \( r \), the error word \( e \) is defined by Equation (7).

\[ e = r \oplus c \]  

(7)

The syndrome \( s \) is defined by Equation (8) with the calculation of modulo 2 additions,

\[ s = rH^T = eH^T \]  

(8)
Figure 10. The factor vectors
where $H$ is called the parity check matrix as

$$ H = \begin{bmatrix} 1 & 0 & 1 & 1 & 0 & 0 \\ 0 & 1 & 1 & 0 & 1 & 0 \\ 1 & 1 & 0 & 0 & 0 & 1 \end{bmatrix} $$

To correct the received word, we used the error word $e$ corresponding to the syndrome $s$ as Table 2.

Table 2 The error word $e$ estimated by the syndrome $s$

<table>
<thead>
<tr>
<th>Syndrome s</th>
<th>Error Word $e$</th>
</tr>
</thead>
<tbody>
<tr>
<td>000</td>
<td>000000</td>
</tr>
<tr>
<td>101</td>
<td>100000</td>
</tr>
<tr>
<td>011</td>
<td>010000</td>
</tr>
<tr>
<td>110</td>
<td>001000</td>
</tr>
<tr>
<td>100</td>
<td>000100</td>
</tr>
<tr>
<td>010</td>
<td>000010</td>
</tr>
<tr>
<td>001</td>
<td>000001</td>
</tr>
<tr>
<td>111</td>
<td>100010</td>
</tr>
</tbody>
</table>

To exploit the bit correcting function, we allotted three bits to the eight colors and had successive two colors represent the $(6, 3)$ code as Table 3. That means one of two successive color balls can be recognized rightly and the other can’t be recognized falsely beyond one bit, the error can be omitted.

Table 3

<table>
<thead>
<tr>
<th></th>
<th>Yellow</th>
<th>100</th>
<th>Green</th>
</tr>
</thead>
<tbody>
<tr>
<td>000</td>
<td>Yellow Green</td>
<td>100</td>
<td>Green</td>
</tr>
<tr>
<td>001</td>
<td>Sky Blue</td>
<td>101</td>
<td>Blue</td>
</tr>
<tr>
<td>010</td>
<td>Yellow</td>
<td>110</td>
<td>Pink</td>
</tr>
<tr>
<td>011</td>
<td>Red</td>
<td>111</td>
<td>Violet</td>
</tr>
</tbody>
</table>

The number of Chinese characters in common use in Japan is 3596. So we prepared 3865 characters including others such as numbers and alphabets. That requires four balls of eight colors, $8^4 = 4096$. The $(6, 4)$ code needs the redundant word of the same length of data word. So we need eight balls for each character.

Experiment

Japanese lyrics are tried to be sent. By the FEC, 43 characters were sent successively and correctly. Without FEC, only a few characters could be sent.

Conclusions

The DSSS modulation has been used effectively. The detected lights are standardized to define the factor loading vectors and the factor vector. The correlation matrix of the detected lights indicate the angles among the factor loading vectors. Rotation arrows to find the factor loading vectors and factor vectors. Japanese lyrics are tested to be sent. By the FEC, 43 characters were sent successively and correctly. Without FEC, only a few characters could be sent. The effect of the FEC has been proved.

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