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A TRIAL OF PROJECT BASED LEARNING CLASSES AS A METHOD TO EDUCATE A STUDENT FOR AN ENGINEER

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Abstract. *The most important work for an engineer is technology development. For the work, an engineer is required to have ability to learn and use science, ability to manage even such issues that can't be solved only by knowledge of science, that is, creativity and ability to plan and conduct necessary tests. To develop such abilities in a student, the traditional one-way education: a teacher gives knowledge to students, seems not to be enough. In an author's experience in a private company, the most effective way for training a freshman into an engineer was the OJT (On the Job Training). The essence of the OJT can be said "to give him/her issues one by one: sometimes difficult and to let him/her work by himself/herself to complete the issues". We have introduced the essence of the OJT into two classes (PBL classes) at UFPE: "Design and Making of a Paper Glider" and "Design and Making of Something to Save an Egg". As a result, we have found the trial was successful.*

Keywords: *Engineer; Technology development; Student's ability; University education; PBL*

1. INTRODUCTION

The main duties of School of Engineering of a university are to conduct such researches that contribute to the industry in the technology development, and to educate the students preparing them for the future engineers. The latter duty is discussed in this paper.

The most important work of an engineer is to develop new technologies. To conduct it, an engineer is required to have "the ability to learn and use the science", the ability to manage even such issues that can't be solved only by using the science, that is, "the creativity" and "the ability to plan and conduct tests" to get data necessary for his/her work or to confirm his/her ideas.

In 2002, The Asahi Shimbun Company, one of the three largest newspaper companies in Japan sent to the tops of 100 main companies (50 from manufacturing industries and other 50 from non-manufacturing industries) in Japan a questionnaire to survey what the companies expect universities to do and whether their expectations are satisfied. The results were disclosed on its newspaper of January 4, 2003 (The Asahi Shimbun Co., 2003). The outline was as follows: 82% of them had not been satisfied with the university education. The reasons for their un-satisfaction were from the top: Not enough education of "creativity" (58 %), "ability to solve problems" (51 %) and "logical thinking" (46 %).

The "ability to solve problems" and "logical thinking" can be covered with the above described abilities required for an engineer. So, the abilities required for an engineer are also the abilities the industry world expects universities to develop in a student.

Compared with the university education in 2002, that at present might have been improved about the above points. For example, at a department of engineering of The University of Tokyo, the students take the ordinary style of classes only in the morning and, in the afternoon, they conduct the projects they have planned (Sato, 2017). At present, more than 50% of professors of the School of Engineering of the university have each an experience of working in a private company (Aihara, 2018).

However, it seems that there still remains such a discrepancy between the industry world' expectation to university education and the actual university education in Japan and in Brazil (Doherty, 2018) also. As the reasons for such discrepancy, the followings can be pointed out: 1. The main part of university education is still that with the traditional

one-way style: a teacher gives knowledge to the students in a class. This style of education is preferable for the professors to give fundamental knowledge to the students. However, it is not always enough to develop the abilities required for an engineer in a student. 2. A consistent or systematic method to develop such abilities in a student has not yet been fully established.

Then, how can we develop such abilities in a student?

We can find a hint in an author [T.Y]'s experience. When he was in a company in Japan, he found that the most effective method to train a freshman into an engineer was the OJT (On the Job Training) (Allen, 1919; Terada, 2009). The essence of OJT is to let a trainee actually work with giving him/her the issues one by one which are sometimes more difficult compared with his/her abilities.

As a result of above discussion, we have designed two university-class versions of OJT (in other word, PBL: Project Based Learning) (Advanced Institute of Industrial Technology, 2018), as a method to develop the abilities required for an engineer in a student, and, tried them at Graduate Program of UFPE. One is "Design and Making of a Paper Glider" (abbreviated "Glider class" or "Glider" hereafter) and another "Design and Making of Something to Save an Egg" (abbreviated "Egg class" or "Egg" hereafter).

At UFPE, PBL classes (Sueoka, 2014 and Aihara, 2018) had been already conducted before us. However, in this paper, we take up only the PBL classes we have designed and tried.

2. OBJECTIVES AND METHODOLOGIES

1) *Objectives of PBL classes:* Through letting a student conduct a technology development which has a smaller scale than that of the actual one but includes the same components as those of the actual one, 1. To develop the abilities required for an engineer in a student. 2. To let the student learn, what a technology development is, how it is conducted and what abilities are required for it. 3. To let the student get interested in the technology development.

2) *Objectives of this paper*: To introduce the 2 PBL classes we have designed and tried at UFPE.
To evaluate the 2 PBL classes from the viewpoints of: 1. How the different education style of PBL class from the traditional class influences the education in a class. 2. Whether the PBL class is really useful for developing the abilities required for an engineer in a student. 3. Points to be improved or to be taken care of in the PBL class.

3) *Methodologies*: We design and try 2 PBL classes at Graduate program at UFPE. We collect the data to evaluate our PBL class trial by the following methods: 1. To conduct questionnaire surveys to the students to know how they evaluate the PBL class. 2. To watch the students in the PBL classes carefully to know how they act there. 3. To let each student write a report of the PBL class which includes his/her evaluation of the class. We evaluate the 2 PBL classes by analyzing and synthesizing all the data we collect through above methods.

3. DESIGN OF PBL CLASSES

1) *Design principle:* (a) *Main components to be included:* We let a student conduct a technology development which is with a smaller scale but has the same components as those of the actual one in the class. That is, the student's work in the class should include the following main components: 1. to clarify the point of issue, 2. to learn and use science, 3. to practice creativity and 4. to plan and conduct necessary tests. (b) *Teacher's work in the class*: On the other hand, in the class, the teacher's work is limited to 1. requisite minimum teaching and 2. accepting any consultation with the students about their work, if asked, to stimulate student's voluntary activity.

2) *Structure of designed PBL class*: (a) *Difference in education style of the PBL class from the traditional class:* Figure 1 shows the difference in education style between the two classes. In the traditional class, the main player is the teacher who gives knowledge to the students. Students are in the passive position where they receive knowledge from the teacher. On the other hand, in the designed PBL class, the main player is the student who works to accomplish his/her issue by him/herself. The teacher is at the position where he/she supports the student. Another characteristic point of the designed PBL class is that the student's work is creative and challenging. (b) *Structure of designed PBL class*: The activities in the PBL class, designed based on the above principles, can be classified into the three groups of work: student's work, teacher's work and joint work.

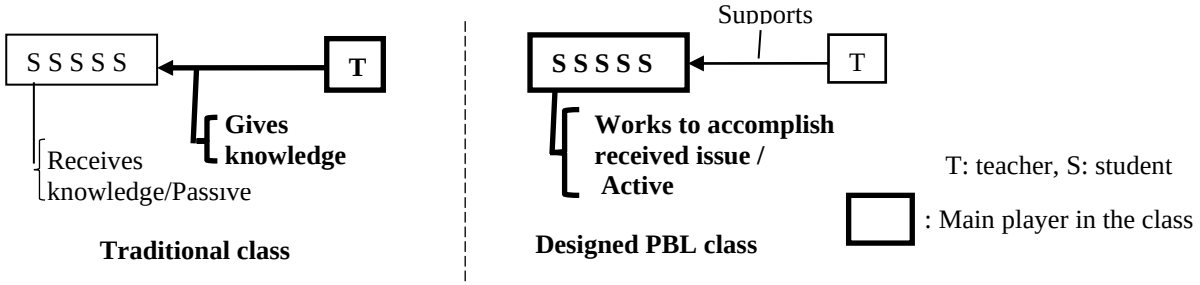

Figure.1 Difference in education style of Designed PBL class from Traditional class

It goes without saying that the most important work of the three ones is the student's work. Therefore, we have to let the student work as much as possible. However, the total hours of a class are limited. So, on the other hand, we have to be careful so that the student doesn't waste much time in the limited hours. To prevent the student from wasting much time, 1. The teacher suggests to the student such information that is important to promote his/her work but is difficult for him/her to get by him/herself in a short time. This is teacher's work. 2. The teacher conducts together with the students such work that we want most them to fully understand and to get accustomed to. This is joint work. The structure of "Egg class" is shown in Fig. 2.

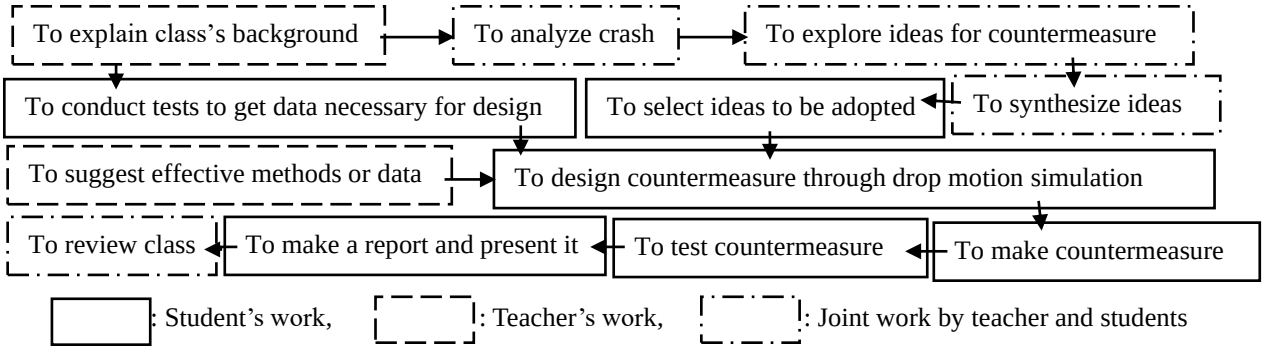

Figure 2 Structure of "Egg class"

4. TRIAL OF PBL CLASSES

1) *Outline of tried PBL classes*: Outline of tried PBL classes is summarized in Tab. 1. "Glider class" was conducted in 2015 and, "Egg class 1" and "Egg class 2" in 2018. The "Egg class 1" differs from "Egg class 2" in term length and countermeasure design condition.

Table 1 Outline of tried PBL classes

Class	"Glider class"	"Egg class 1"	"Egg class 2"
Term (length)	11-12/2015 (3 weeks)	3-6/2018 (15 weeks)	6/2018 (3 weeks)
Total hours	32	30	30
Student number	20	3	5
Issue	To develop a paper glider	To develop a counter measure to save a dropped egg	
Design condition	Paper glider weight≥5gf	H (Egg drop height)=2.5m, Budget≦10 Reals	H=5.15m, Material: news papers less than 10 sheets
Report by student	-	Made	Made
Presentation	Oral	Presentation of report	Presentation of report
Review of class	In a review form	In a review form	In a review form

2) *Trial of main components in the PBL class*: The main components of the PBL class we have designed are same as those of the actual technology development as written in 3. In the following, it is explained with typical examples how these main components have been conducted in the class mainly on "Egg class".

To clarify the point of issue: Through the discussion with the students, the teacher lets the students derive the equation (1) and Fig. 3 by using "Newton's law of motion 2". From Equation (1) and Fig. 3, the students realize that what they should do is "to decrease V" or "to increase Δt".

$$F=(W/g)*\{(0-V)/\Delta t\} \quad (1)$$

Where
F (kgf): reaction force an egg receives from the ground during its crash
V (ms^{-1}): drop speed of the egg when it touches the ground
Δt (s): time from the egg's touch to the ground to its crash
W (kgf): the egg' s weight
g (ms^{-2}): gravitational acceleration

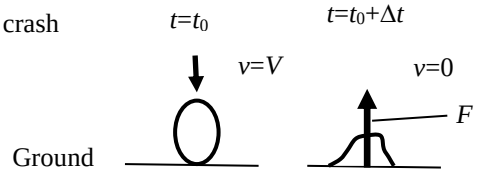

Figure 3 Modelling of an egg's crash with ground

To learn and use science: The students have used "Newton's law of motion 2" to clarify the point of issue as written above and used its result to explore the ideas to save a dropped egg from being crashed. Besides the above, they have

used such science as “Brainstorming” (Osborn, 1953) to explore the ideas, and “KJ method” (Kawakita, 1967) to synthesize the obtained ideas, “Newton’s law of motion 2” to simulate egg’s drop motion, “Runge-Kutta method” to solve non-linear differential equations for the simulation and “Simpson’s equation” to integrate the drop speed.

Figure 4 shows a result of egg’s drop motion simulation by a student (Doherty, 2018): the change of egg’s drop speed with its immersion after entering the water. From the simulation, the student could realize that at the immersion 0.2m, the egg’s drop speed saturates to 0.3m/s (low enough to save an egg) and, therefore, that the necessary water depth is larger than 0.2m.

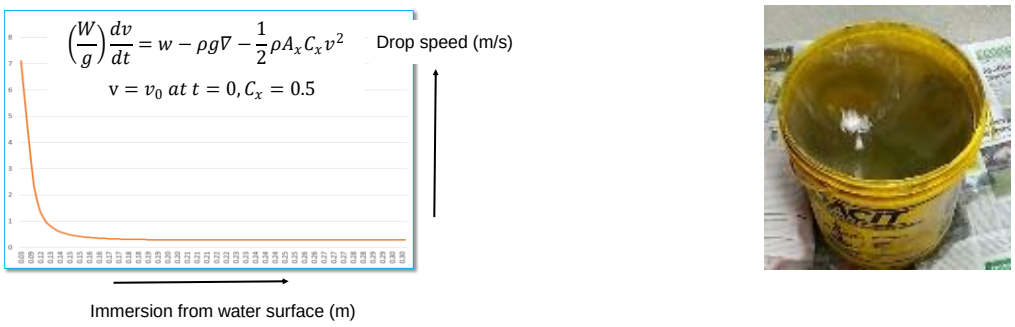

Figure 4 (Left): A result of simulation of egg’s drop motion after its entering water, (Right): Observed water surface at the moment when a dropped egg has begun to enter water: “Egg class 1”

To practice creativity: The students must have practiced their creativity to explore ideas to save a dropped egg with “Brain storming”, to synthesize the ideas with “KJ-method” to adopt some of them, to make a model to simulate the egg drop motion, to transform the idea into a practical design and further to prepare facilities for such tests as shown in Fig. 5.

To plan and conduct necessary tests: In “Egg class 2”, the force an egg receives from newspaper sheets during the egg breaks the sheets (1 to 4 sheets) was measured by students with the apparatus shown in Fig. 5. The force displayed on the balance was recorded with a video camera. The peak of the force got through analysis of the record is shown with a graph in Fig. 5 and Tab. 2. The data was used for design of a cone with some horizontal sheets inside by simulation. Egg break tests were also conducted to get the minimum load which breaks an egg.

Confirmation tests: The objects that the students had developed were checked whether they had intended performances or functions by confirmation tests at the ends of the classes. The test results are summarized below:
“Glider class”: The confirmation test results of PG-2s (completed paper gliders) are summarized in Tab. 3. All of 5 groups accomplished the issue: glide ratio more than 5. The PG-2 developed by Group 4 showed the best performance.
“Egg class”: *The* confirmation test results are summarized in Tab. 4. In “Egg class 1”, all the eggs were saved. In “Egg class 2”, only Egg No. 1 failed to be saved. Egg No. 1 dropped near the edge of the top sheet of the cone, after bounded to the top sheet, went over the edge wall, dropped to the ground and was crashed as shown in Fig. 6. The student who has developed the countermeasure for Egg No. 1 discussed the failure as follows (da Silva, 2018): 1. If it had dropped near the center of the top sheet, it might have broken the top sheet, entered the cone and been saved. 2. Another possibility: If the top sheet had been made with one layer of newspaper (not with two layers adopted to tested cone), the egg might have broken the top sheet and been saved same as written in above 1.

Figure 7 shows the difference of egg inside before and after dropped, which was taken with X-ray digital radiography. Only Egg No. 10 shows no change in 4 saved eggs of “Egg class 2”. This difference seems to be caused by the different impact shocks to eggs at their landing. Egg No. 10 on a parachute landed most softly of the tested 5 eggs.

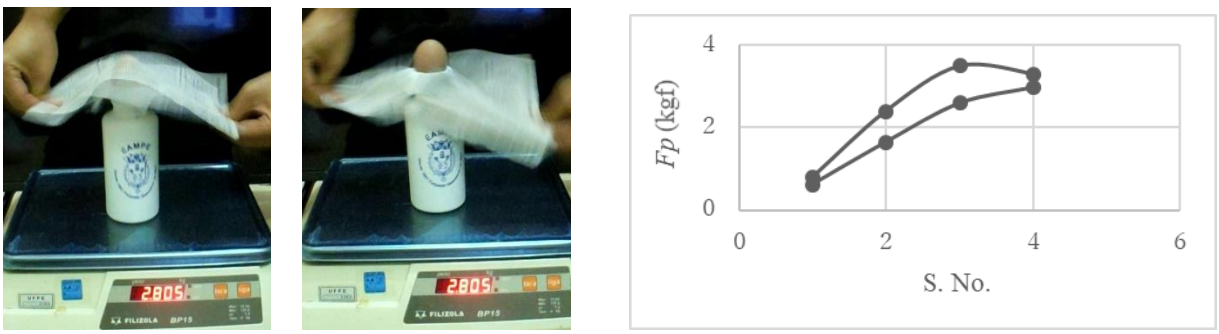

Figure 5 Measurement of force an egg receives from newspaper sheets during it breaks them, Photos: [Left] Just before break, [Right] Just after break, Graph: Test results: “Egg class 2”

Table 2 Results of measurement of force an egg receives from newspaper sheets during it breaks them: "Egg class 2"

T. No.	5	6	7	8	Remarks
S. No.	1	1	2	2	T. No.: Test number
Fp (kgf)	0.790	0.620	2.395	1.645	S. No.: Number of tested newspaper sheets
T. No.	9	10	11	12	*Fp* (kgf): Peak of force an egg receives from newspaper (s) during it breaks them.
S. No.	3	3	4	4	
Fp (kgf)	3.485	2.585	2.970	3.295	

Table 3 Summary of confirmation test results (mean of 5 flight tests): "Glider class"

G. No.	z (cm)	x (cm)	t (s)	x/z (-)	z/t (cm/s)	Remarks
1	80	662	1.72	8.28	46.4	G. No.: Group number
2	84.5	554	1.00	5.54	84.3	z: Catapult upper surface height above the ground
3	80	648	0.81	8.10	99.3	x: Longitudinal flight distance
4	77	799	2.31	10.38	33.3	t: Time from launch to landing
5	84.5	843	2.01	9.98	42.0	x/z: Glide ratio, z/t: Sink rate

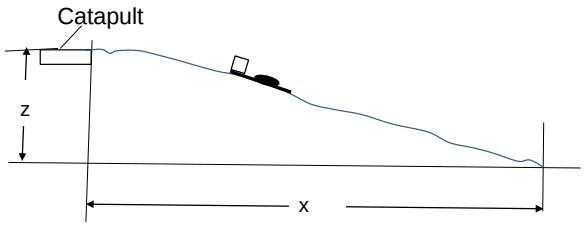

Table 4 Summary of confirmation test results: "Egg class"

S.No. (Egg No.)	H (m)	Countermeasure	R	Remarks
1	2.5	Newspaper cushion on the ground	S	S. No.: Student number
2		Water in a bucket	S	H: Egg drop height
3		Newspaper shield around an egg	S	R: Result of test
4 (8)	5.15	Piled air-cushions made with newspaper sheets	S	S: Saved the egg
5 (1)		A cone, set at ground, with 4-layer sheets in it	F	F: Failed to save the egg
6 (6)		4 floor slider	S	"Egg class 1": S. Nos. 1-3
7 (10)		A parachute over an egg	S	"Egg class 2": S. Nos. 4-8
8 (11)		A cone, attached to an egg, with 3-layer sheets and a bottom pillar in it	S	

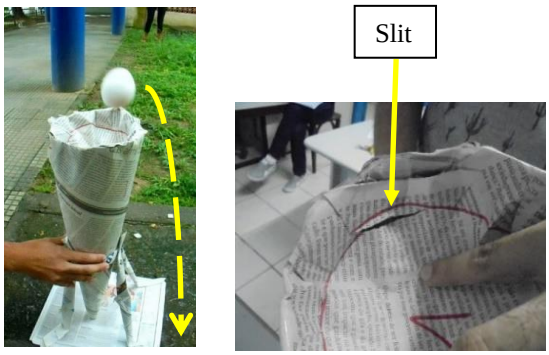

Figure 6 (Left): "Egg No. 1" at highest position after bounding, (Right): A split at edge of top sheet found after test: "Egg class 2"

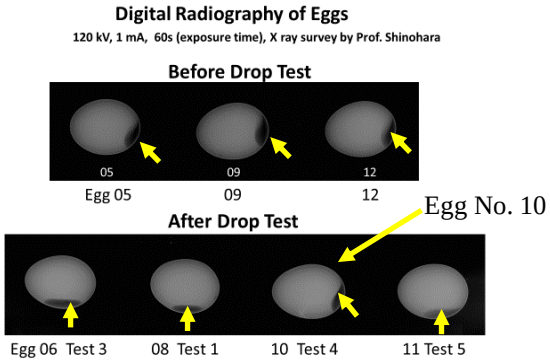

Figure 7 Egg inside before and after dropped by radiography: "Egg class 2"

5. DATA COLLECTION FOR EVALUATION OF CONDUCTED PBL CLASSES

1) *Questionnaire survey to students attended PBL class:* The form of the questionnaire is shown in Tab. 5. The number of the students who replied to the questionnaire is 17 from "Glider class" and 8 from "Egg class". Results of the questionnaire are summarized in Appendix 1.

Table 5 Questionnaire to students attended PBL class

Items	Reply (select one)	Comments
(1) About structure of class		
1) Time for class	Too long, Normal, Too short	
2) Practice by student	Too much, Adequate, Too little	
3) Teaching by teacher	Too much, Adequate, Too little	
4) Structure of class	Good, Normal, Bad	
(2) About student's interest in class		
1) Subject	Interesting, Medium, Not interesting	
2) Class	Interesting, Medium, Not intersting	
(3) About what student has got in class		
1) Found science and/or technology in class?	Yes, No	
(4) About improvement of class and others		
1) Points to be improved and others		

2) *Observation of students' activities*: The teacher has watched the students in the PBL classes carefully whole the time. The following is an example which shows that the students were active: At the 2nd "Glider class", 5 groups each presented their efforts to manage to fly PG-1 (the first paper glider), and then actually tried to fly PG-1. After the class, the 6 students who couldn't attend the 1st class and get the homework to fly PG-1 came to the teacher and said they also wanted to fly PG-1. The teacher gave them the same homework. At the next 3rd class, they presented their efforts and tried to fly their PG-1s.

Figures in Fig. 8 are the records of students' activities in the classes. Sudents were really active and serious. No student seemed sleepy or not-motivated. It was nice for the teacher to watch the students tackling their issues seriously.

Figure 8 (Left) Four group students discussing design of PG-2: "Glider class", (Middle) Students tackling egg drop motion simulation: "Egg class 1", (Right): Students discussing egg drop motion simulation model: "Egg class 2"

3) *Reports by students:* We can find the student's evaluation of the PBL class in his/her report also, in addition to the above questionnaire results. In "Glider class", before each group's conducting final flight tests on their PG-2, they orally presented their development of PG-2 and we didn't ask them to write their report of their activities. In "Egg class 1" and "Egg class 2", we asked each student to write his/her report of activities. The last words in the reports by the three students of "Egg class 1" are shown in Appendix 2 (da Rocha, Doherty and Fabricio Filho, 2018).

6. EVALUATION OF CONDUCTED PBL CLASSES

1) *Influence of different education style of the PBL class on education in a class:* The important factors which make the education in a class more effective are: 1. Many students get interested in the class, 2. Many students get active in the class and 3. Many students get what the teacher has intended in the class. Therefore, in the following, it is discussed how the different education style of PBL class has influenced the education in the classes from these three viewpoints.

Student's interest in the PBL classes: From the results of questionnaire "(2) About student's interest in class" shown in Appendix 1, we can realize that many students were interested in the "subjects" (71-100 %) and in "classes" themselves (88-100%). We can find some of the reasons why many students have got so interested in the classes, in their comments. We have summarized the reasons in Tab. 6. From those comments, we can realize that, through "to

work by him/herself", the students have found the "different points from the traditional class" in the PBL classes and got interested in the PBL classes.

Table 6 Reasons why students have got interested in PBL class from (2) of Appendix 1

"The class is different from the ordinally one, and so, students get more interested in the class and become more active" (Glider class, Egg class 1 and Egg class 2), "A good combination of the old school lecture and its practice by students" (Glider class), "Well administrated" (Egg class 1)
"The class has a factor of challenging" (Egg class 1), **"**Quite interaction between the teacher and the students in the class" (Glider class), "A place where each student can act based on his/her own decisions, which is new to them" (Egg class 1)

Student's activities in the PBL classes: From the teacher's observation of the students in 5, we can say that many students were active enough in the whole classes. What has let the students be so active? From Tab. 6, we can realize that It was their "to work by him/herself" for "challenging issues" by "combination of theory and practice".

What a student has got in the PBL class: From the results of questionnaire "(3) About what student has got in class" in Appendix 1, we can realize that many students (94-100 %) "felt or found science and/or technology in the PBL class". We can find the contents of their "feeling or finding" in their comments. We have summarized the contents in Tab. 7. From Tab. 7, we can realize that they recognize that they have conducted technology development with taking necessary fundamental procedures: they have used science for design, created simulation models etc., used tests to confirm their hypothesis or to improve their objects, and that it was a new experience for them. It is more than only "felt or found science and/or technology". It shows that the objectives of PBL class written in 2 have been almost accomplished.

Table 7 Contents of students' "felt or found science or technology in PBL class" from (3) of Appendix 1

"The students needed science and technology to solve their issues" (Glider class), "Not only I found science in the class, but I also had to use it, which I never had before in other classes" (Egg class 2), "The students had an opportunity to design something based on theory, create simulation models, improve models with experimental data, make hypothesis and check them" (Egg class 1), "The students used science and developed technology in the situation needed to think a lot to design countermeasures". "They felt it nice" (Egg class 1), "Good combination of science and doing in practice" (Glider class)

We can find the student's evaluation of the PBL class in his/her report also, in addition to the above questionnaire results. The last words in the reports by the three students of "Egg class 1" are shown in Appendix 2 (da Rocha, Doherty and Fabricio Filho, 2018). The last words clearly tell how they evaluate the PBL class and what they have got from the PBL class. The last words can be summarized as follows:

A student says that, first, he has got confused with the different education style, for example, with being required to have his own idea. However, after the PBL class, the students evaluate the PBL class as follows: 1. Interesting points: They have got interested in challenging work such as design through simulation. 2. Impressive points: The procedure of the class from "to clarify the essence of issue" to "confirmation tests" has made the student's work go ahead smoothly. Such teacher's organization as design of above procedure seems important to run the class effectively. 3. How to get creativity: They can earn their creativity only with their practice and more practice. 4. Usefulness of the class: The procedure the students took in the PBL class is very useful to solve complex issues. The PBL class is helpful to develop the students as future engineers. 5. Comparison with other classes: Compared with the PBL class, most of the present classes in the graduate course are straightforward and closed-minded.

From the above discussion, we can say that the different education style of PBL class from the traditional education can largely improve the education in a class from any of the three viewpoints.

2) *Usefulness of PBL class for developing abilities required for an engineer in a student*: The theme in this section is same as the question whether the objectives of the PBL class written in 2 have been accomplished or not. We have already discussed the results of PBL classes in this section. Therefore, we can summarize the replies to the above question as written in Tab. 8. From Tab. 8, we can say that the PBL class we have designed and tried is useful for developing the abilities required for an engineer in a student.

3) *Points to be improved or to be taken care of in PBL class*:

Arrangement of classes in calendar: Comparing the students' works between "Egg class 1" and "Egg class 2", we find some differences between them. The total class hours: 30 hours are same. The difference is in their term length: 15 weeks of "Egg class 1" and 3 weeks of "Egg class 2". A student commented "For me, the best thing was the change from one week (of other PBL class) to 4 week-course (of 'Egg class 2')". These matters seem to show that the longer interval between successive two classes gives the students more time "to review the previous class" and "to prepare for the next class". We should consider this point when we arrange our PBL classes in calendar.

To increase the number of PBL classes: We have to increase the number of PBL classes so that a student can take the PBL class repeatedly. The reason is that only one PBL class is not always enough to develop the abilities required for an engineer in a student.

Table 8 Accomplishment of objectives of PBL class

Objective 1) To develop abilities required for an engineer in a student
In PBL classes, almost all the students have tackled the technology development seriously and aggressively as written in 5 and 6 and, have completed it as written in 4. Their such activities surely develop the abilities necessary for an engineer in them. Some students actually think so by themselves as already written in 6. With such data, we have confirmed that PBL class is useful for developing the abilities in a student.
Objective 2) To let a student learn technology development
Through conducting the technology development, many students (94-100 %) have learnt what technology development is, how it is conducted and what abilities are required for it, as already written in 6.
Objective 3) To let a student get interested in technology development
Through conducting the technology development, many students (70-100) have got interested in the technology development, as already written in 6,

7. CONCLUSIONS

On our reflection that the traditional one-way education seems not enough to develop the abilities required for an engineer in a student, and further on the assumption that the OJT (PBL) is preferable to develop such abilities in a student, we have designed two university-class versions of OJT (PBL classes) and tried them at Graduate Program of UFPE. As a result, we have got the following conclusions:

1) *Influence of the different education style of the PBL class from the traditional class on education in a class:* The largest differences in education style of the PBL class from the traditional class are: 1. “Each student works by him/herself in the class” and 2. “The work is creative and challenging”. The differences have let many students: 1. get much interested in the class, 2. get very active in the class and 3. have got what the teacher has intended in the class. That is, we have confirmed that the differences make the education in the PBL class much more effective.

2) *Usefulness of the PBL class for developing the abilities required for an engineer in a student:* In PBL classes, almost all the students have tackled the technology development seriously and aggressively and, have completed it. Some students commented that the PBL class is helpful to develop the students as future engineers. Therefore, we can say, we have confirmed that PBL class is useful for developing such abilities in a student.

3) *Points to be improved or to be taken care of in PBL class:* 1. *Arrangement of classes in calendar*: The longer interval between successive two classes seems better. 2. *To increase the number of PBL classes*: The number of PBL classes should be increased, because only one PBL class is not always enough for the objective.

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10. APPENDICES

Appendix 1: Results of questionnaire to students attended PBL class

(1) *About structure of class*

1) *Time for class*

Class	Too long	Normal	Too short	Impressive comments
Glider	0	82.4%	17.6%	Too short: "The time for the teacher's explanation of the design method was too short for me to understand it well" (Glider) Normal: "The first two classes (introduction) were too long" (Glider) Too short: "The time for the classes could have been longer" (Egg 1)
Egg	0	85.7	14.3	

2) *Practice by student*

Class	Too much	Adequate	Too little	Impressive comments:
Glider	5.9%	94.1%	0	Too little: "I think it should have more days dedicated to practice activities" (Egg 2) Adequate: "The students could make things based on their own ideas, which is something new to them" (Egg 1)
Egg	0	85.7	14.3	

3) *Teaching by teacher*

Class	Too much	Adequate	Too little	Impressive comments
Glider	11.8%	70.6%	17.6%	Too much: "The teacher helped us too much (during preliminary test flights)" (Glider) Too little: "The teach by the teacher was too little for the student to learn well (Glider)
Egg	0	100	0	

Adequate: "The teach was very attentive, interacted with the students" (Glider)

4) *Structure of class*

Class	Good	Normal	Bad	Impressive comments
Glider	82.4%	17.6%	0%	Good: "The sequence of the class facilitated the learning".
Egg	71.4	28.6	0	Good: "The idea of following this structure: theory, design, simulation and validation was nice" (Egg 1)

(2) *About a student's interest in class*

1) *Interest in subject*

Class	Interesting	Medium	Not interesting	Impressive comments
Glider	70.6%	29.4%	0%	Interesting: "The subject was very interesting, because we had never talked about it in class"
Egg	100	0	0	Interesting: "In my opinion, besides it's a simple idea, it's quite challenging" (Egg 1)

2) *Interest in class*

Class	Interesting	Medium	Not interesting	
Glider	88.2%	11.8%	0%	Interesting: "I think your class was a great mixture of old school lecture and doing stuff in action!" (Glider), "I felt that we could take our own decisions, so it was really interesting", "Quite interact between the teacher and the students" (Egg 1)
Egg	100	0	0	

Interesting: "The lectures were well administrated" (Egg 1)

(3) *About what a student has got in class*

1) *Felt or found science and/or technology in class?*

Class	Yes	No	Impressive comments
Glider	94.1%	5.9%	Yes: "We had to solve the problems and needed it: technology and science".
Egg	100	0	Yes: "I had the opportunity to design something based on theory, create simulation models, improve models with experimental data, make hypothesis and check them. The science and technology were nicely developed during classes, since we needed to think a lot to design the countermeasure" (Egg 1), "Not only I found science in the class, but I also had to use it, which I never had before in other classes" (Egg 2)

(4) *About improvement of class and others*

1) *Points to be improved and others*

Class	Comments
Glider	"Only the two first classes were too long. The class that discussed the theory of flight was a bit short to present the subject properly"
Egg 1	"I really enjoyed the class and I feel that I acquired a good amount of knowledge. The only thing I would change is the way of measuring time (maybe using a high-speed camera)"
Egg 2	"For me the best thing was the change from one week to 4 week-course, everything else was good"

Appendix 2: Last words in the reports by three students of "Egg class 1"

It is clear that the challenge proposed is a very useful way to train the student's creativity and capability to solve complex problems. Further, correlating a virtual model with its actual model eases the consolidation of the science concepts learned in classes and helps to better understand it. Therefore, this class is very helpful to the student's development as future engineers, who will be constantly demanded to think outside the box and solve new problems with unknown solutions. (da Rocha, 2018)

Regarding the science and creativity practiced, the class showed up to be really interesting, as it developed gradually from the study, simulation, design, manufacture and analysis. In addition to that, mainly the design and analysis were challenging, as it was necessary a lot of thinking to understand completely the egg's motion and its results. Lastly, it is important to add that this kind of classes should be encouraged, as most of engineering classes in the graduation course are mostly straightforward and close-minded. (Doherty, 2018)

This class was very interesting and funny at the same time. I think it suffered us to learn in a ludic manner, allowed us to be protagonists of our own ideas. It was a very open class without losing the focus. This I have learned:
- Creativity is something that we can earn with practice and more practice.
- In design step, we first need to decide which parameters are most important, trying to make things simple.
- Making reports of the things we have done is important, lest the information be lost with time.
- Organization is crucial to make things to get things moving. Professor himself gave an extraordinary lesson of organization. (Fabricio Filho, 2018)

11. RESPONSIBILITY NOTICE

The authors are the only responsible for the printed material included in this paper.