https://doi.org/10.20965/jaciii.2015.p0307

Paper:

Active Learning Based on Manual Skills for Students in Mechatronics Course

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[Received June 14, 2014; accepted December 20, 2014]

There is a growing trend at universities to switch from conventional teaching methods, which focus on knowledge transfer, to methods based on the concept of active learning. Many such methods have been devised and tested to show the validity of this concept. In this study, a project was designed and implemented that teaches some simple principles of aeronautics by having students construct and fly a remote-controlled (RC) model airplane. The goals are to motivate students to study mechatronics and to foster teamwork and communication. This paper explains the project. Its effectiveness was demonstrated in three trials with three groups of students.

Keywords: engineering education, active learning, control engineering, team learning

1. Introduction

Conventional teaching methods focus on knowledge transfer, with the main form of interaction being one-directional lectures from teacher to student. There are several problems with this kind of teaching:

1. It is difficult for students to maintain a strong motivation to study.
2. It is difficult for them to apply what is learned in a practical way.
3. It is difficult for them to actively discover problems.
4. There is no practical training.
5. There is no opportunity for teamwork or communication among students.

Active-learning methods seek to avoid these problems, and many have been investigated and tried out [1–3]. Efforts in this field have been accelerating during the last decade, particularly in the areas of participatory learning (group work, discussions, etc.) [4], e-portfolio [5], and blended learning [6].

This paper describes participatory learning in a course for second-year students in the School of Computer Science at the Tokyo University of Technology. A project was set up involving the construction of a remote-controlled (RC) model airplane to stimulate students' interest in mechatronics and engineering, to improve their motivation for self-learning, and to foster their communication and teamwork skills.

2. Project Design

This section explains the design of a project involving the construction of an RC model airplane as an implementation of active learning, and it presents some of the design considerations.

There were seven courses of study in the School of Computer Science at the Tokyo University of Technology in 2013. At the end of their freshman year, students had to select one course of study that they would pursue for the remaining three years of their undergraduate education. One of the courses was mechatronics.

In the first term of their sophomore year, new students in the mechatronics course took a class called Mechatronics Lab. The purpose of the class was to foster an interest in electronics, electrotechnology, mechanical engineering, information technology, and control theory. The class lasted for 15 weeks. It was held once a week, and each session lasted for 1.5 h $\times$ 2. In the first and last two weeks, orientation and wrap-up sessions were held in a classroom. A total of about 30 students took the class. Five projects were set up in five different laboratories in the school, and students were required to take four of them. They worked on each project for three weeks, and then rotated to another project.

The project that is the subject of this paper was taught

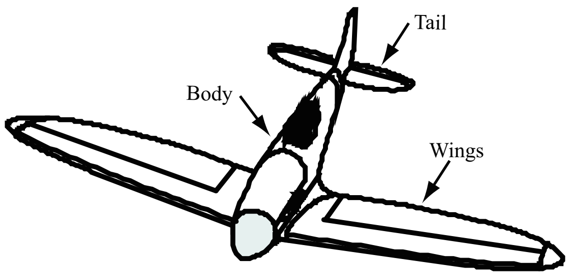

Fig. 1. Basic structure of airplane.

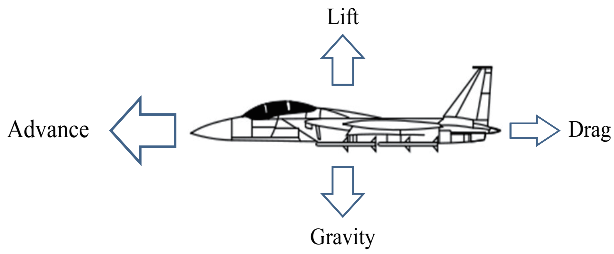

Fig. 2. Forces acting on airplane.

in the She Lab of the School of Computer Science at the Tokyo University of Technology. A total of 15 students participated in this project. Since they did not have much expertise in either mechatronics or working with their hands, and since model vehicles are a popular hobby among young people, we chose the construction of an RC model airplane for this project. The project goals were

1st week: to understand the basic principle of how an airplane works and a dynamic mathematical model of an airplane (classroom lecture),

2nd week: to work on constructing an RC model airplane, and

3rd week: to finish the construction and to carry out flight tests (experiments).

The first week of the class had two parts: (1) studying the basic structure of an airplane, its aerodynamics, and the principles of flight and (2) using the free program Scilab to carry out simulations based on a mathematical model of an airplane to gain a deeper understanding of the theory studied in the first part. This was the first time for most students to use Scilab, so they had to install it on their personal computers before coming to class. Since there was not enough time to perform simulations on acceleration and deceleration and since the main purpose of the class was to stimulate students' interest in mechatronics, we focused on understanding the kinetics of flight at a constant speed.

The topics covered in the lectures in the first part of the first week are reviewed below.

There are basically two types of aircraft: lighter-than-air (such as a hot-air balloon) and heavier-than-air (such as an airplane). Airplanes are further divided into the fixed-wing type (such as a Boeing jet airliner) and the rotary-wing type (such as a helicopter).

The three main parts of an airplane are the body, the wings (= airfoils), and the tail (**Fig. 1**) [7]. The tail stabilizes the body and adjusts the attitude of the plane. The wings produce aerodynamic lift when the plane moves forward. The forces acting on an airplane are weight, lift, thrust, and drag (**Fig. 2**). The engine produces thrust, which pushes the airplane forward, resulting in a flow of air over and under the wings. The difference in air pressure on the upper and lower surfaces of the wings produces lift. When the lift is greater than the weight, the

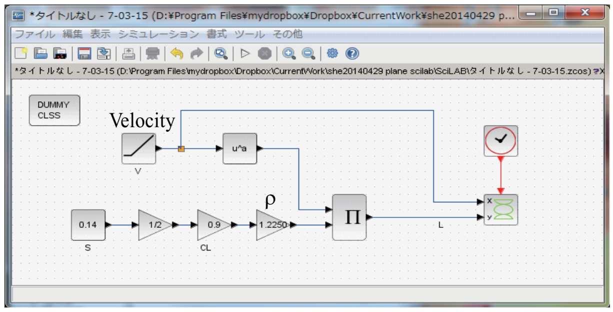

Fig. 3. Scilab simulator for examining relationship between lift, L, and ground speed, V.

airplane rises; and when the lift equals the weight, the airplane flies horizontally. A dynamic model of an airplane can be constructed based on Newton's laws of motion.

The relationship between lift and the area of an airfoil for a constant flight speed is

$$L = \frac{1}{2}\rho C_L S V^2, \quad \ldots \ldots \ldots \ldots \quad (1)$$

where the parameters are

C_L: coefficient of lift [s^3/m^4]

ρ: density of air [kg/m^3]
(Value at sea level: 1.2250 kg/m^3)

V: ground speed [m/s]

S: surface area of airfoil [m^2]

L: lift [N].

In the second part of the first week, students used Scilab to explore the relationships Eq. (1) among lift, speed, and the area of an airfoil to gain an understanding of the principle of flight. **Fig. 3** shows a screen shot of a Scilab simulator for examining the relationship between lift and ground speed [8].

After the first week, the students in each group were divided into two small subgroups. During the second week and the first half of the third week, each subgroup constructed an RC model airplane. The model contained very simple electronic and mechanical parts, although some students were probably not familiar with them. Moreover, a model airplane is fun to play with. These considerations make it a perfect learning tool for students in this type of class.

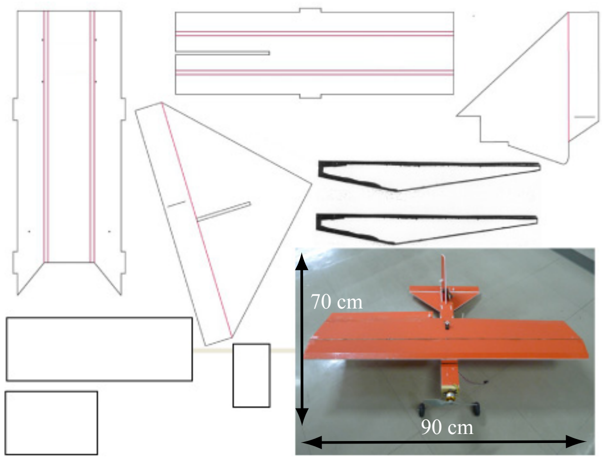

Fig. 4. Design of model airplane.

Table 1. Parameters of plane body.

Length of wing	Length of body	Weight
90 cm	60 cm	500 g

An RC model airplane consists of the airplane itself and a controller, which is a radio transceiver [9]. The transceiver receives control signals from a transmitter and sends three types of control signals to three servo motors on the airplane, which control the rudder, the elevators, and the ailerons. This system makes the model act like a real airplane and enables it to perform tasks.

Students constructed the model out of expanded polystyrene (**Fig. 4**). Since some students had little experience in this kind of work, the experienced students were encouraged to take responsibility for the construction and to teach the others. After the group had discussed the problem, the group leader assigned jobs to everyone, and they worked together to build the model. **Table 1** shows the size of the model airplane. Note that the weight includes everything in the model [motors, propeller, battery, etc. (**Fig. 5**, **Tables 2, 3**)].

During the second half of the third week, the students went outside to an open area on the Hachioji campus of the university and tested their airplanes. Since control of the flight of an airplane is intuitive, an airplane is a good way to explain some basic control methods. The students were given a short introduction to PID control before the test. Note that Scilab provides an environment in which PID control can be used in simulations: It is only necessary to click on the PID icon in Xcos and drop it onto a simulation sheet.

3. Implementation and Evaluation

In the first half of the first week, students attended ordinary classroom lectures. Since the number of students was small, we tried to encourage them to use the knowledge they already had to explain flight and to ask questions.

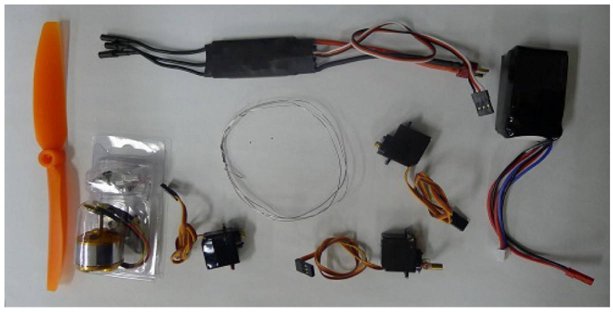

Fig. 5. Parts of model airplane except for body.

Table 2. List of other parts (ESC: electronic speed controller).

Motor & ESC	Servo motor	Battery
1 set	3	1
Propeller	Steel wire ($\phi = 1$ mm)	
1	80 cm	

Table 3. Parameters of parts in **Table 2**.

Propeller: 8060 (length: 8 inches; thread pitch: 6 inches)				
ESC: 30 A				
Motor: A2212, K_V: 1400 V/rpm				
Volts [V]	Amps [A]	Watts [W]	Thrust [g]	Efficiency [g/W]
7.0	11.4	79.8	410	5.14

In the second half of the first week, the students started using Scilab, usually for the first time. So learning how to use it was time-consuming. Students who finished quickly helped the others; and all of them compared results with each other for airplanes of different sizes. There was not enough time for everyone to become sufficiently skillful in using the program; so some study had to be done after class.

The students exchanged contact information so that they could get together outside of class and discuss unfinished work.

Figure 6 is a photograph of students hard at work making model airplanes. Since it was the first time for them to build such a model, they made mistakes; and extra raw material was provided to redo unusable parts. In fact, students were not told that they had cut a piece in the wrong way; they were allowed to discover the mistake themselves. The only time that they were given assistance in building a model was when the model had to be balanced, which seemed to be a little too difficult for them.

Each team had to tune their airplane and make final adjustments before the test flight. The tuning process requires skill, and the students were given assistance in this. The students tried to operate their model first on the ground. After they became familiar with the controls of the radio controller, they tried to fly the model. Finally, two teams competed to see which one could fly longer. It

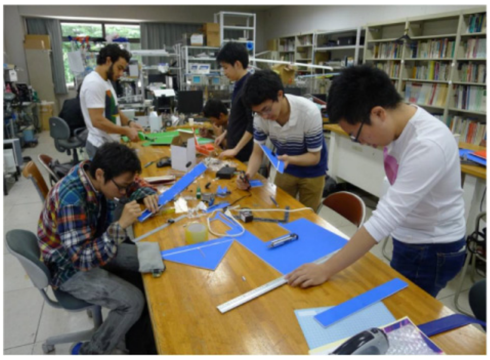

Fig. 6. Photograph of students making model airplanes.

Fig. 7. Test flights.

is not easy to take off and land safely, and at least four extra propellers were made available for every test. **Fig. 7** shows some photographs of test flights.

After the test flights, the students were given a questionnaire so that the project could be evaluated. A total of 15 students in three groups took part in the project in 2014. The questionnaire was given to two of the groups, which comprised 10 students. It contained four questions:

Q1: Have you ever had any experience building models?

Q2: Were you interested in mechatronics before participating in this project?

Q3: Did you become more interested in mechatronics after participating in this project?

Q4: Do you think that your participation in this project increased your motivation to study mechatronics?

Each question had four multiple-choice answers: (1) a great deal, (2) a moderate amount, (3) not very much, and (4) not at all. **Fig. 8** shows the results: The project made 60% of the students more interested in mechatronics, and it made 70% of them more motivated to study.

4. Conclusion

In this study, a project was designed that involved the construction of an RC model airplane as an implementation of active learning so as to stimulate students' interest in mechatronics and their motivation to study it.

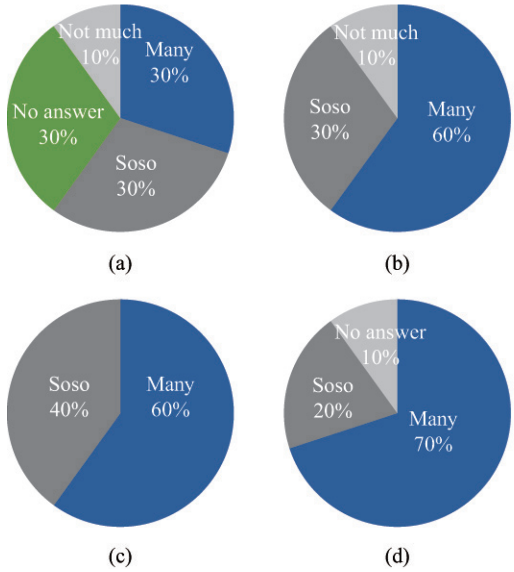

Fig. 8. Results of questionnaire: (a) Q1, (b) Q2, (c) Q3, and (d) Q4.

The project lasted for three weeks. In the first week, students studied the basics of airplanes in lectures and through simulations using Scilab. Then, they were divided into small groups. In the second week and the first half of the third week, each group constructed an RC model airplane. Finally, they tested their airplanes.

The project encouraged them to discuss the theory of motion during the learning process and to test out their ideas through simulations using Scilab. The last two weeks gave them an opportunity to communicate with each other and to work together on building a model airplane.

The project made the students more interested in mechatronics, as revealed by a questionnaire; and it also helped them to communicate more actively with each other and to learn how work as a team.

The results show that the construction of an RC model airplane was an excellent project for students, and that the students were very eager to participate. In the future, this type of project needs to be given to more students so that its effectiveness can be evaluated more fully, and a more comprehensive questionnaire needs to be made to see to what extent the goals of the project are achieved. This will result in an objective evaluation and provide hints on how to improve the content of the project. These ideas will be implemented next year.

Acknowledgements

This work was supported in part by the Grant-in-Aid for Scientific Research (C), Japan Society for the Promotion of Science (JSPS) under Grant No. 26370639.

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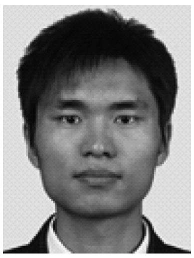

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