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The role of the Center for Mathematical Modeling and Simulation, Institut Teknologi Bandung, at Mathematical Modeling Course at Department of Mathematics, Institut Teknologi Bandung

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Abstract

Mathematical Modeling Course at the Department of Mathematics, Institut Teknologi Bandung, is designed to train students in mathematical modeling process of real-world problems. During this course, students work in groups of four to five students in which each group is assigned with a real-world problem to be solved. By the end of the course each group should be able to formulate a mathematical model of the assigned problem, apply mathematical skills to analyze and solve the problem, then to interpret the mathematical results and present the results. One of the essential things in managing this course is providing a number of real-world problems to be solved by students, since only by working with real-world problems which have not been written in mathematical formulation, the students can experience themselves the complete process of modeling, especially validating the mathematical results with real data.

The Center for Mathematical Modeling and Simulation, Institut Teknologi Bandung, which is founded in 1994 to promote the roles of mathematics in modeling and simulation, has a significant role in providing the problems. Collaborations with a number of institutions, national as well as international, have been built and constantly developed by the center. This paper discusses how the mathematical modeling course is managed and improved, where we give an emphasizing on how researchers at the center, which are also assigned as supervisors at the mathematical modeling course, prepare students-workable problems based on the experiences from the collaborations. In this paper, we show that the mathematical modeling course at the Department of Mathematics, Institut Teknologi Bandung, is regarded by the students as a course that can bridge their mathematical skills and the application of mathematics in solving real problems in Indonesia and can improve the students soft skills especially in communication and team-work capability.

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1. Introduction

During the last couples of decades, many countries around the world make mathematics curricula reforms, especially at secondary level, in which emphasizing in mathematical modeling is regarded as an important element in an up-to date mathematics curricula preparing generally for further education(Kaiser, Blomhøj and Sriraman[12]).While in Indonesia, mathematics curricula at basic and secondary schools still do not give an appropriate portion on improvement on mathematical modeling competence. It follows that when entering universities, Indonesian students have a lower mathematical modeling competence compared to undergraduate students from others countries which have introduced mathematical modeling process in basic and secondary schools. Whereas, it is an evitable fact that nowadays mathematical modeling has a key role in the development of science and engineering, also in fields such as the environment and industry, while its potential contribution in many other areas is becoming more and more evident (Quarteroni[14]). If the lack of mathematical modeling competence is not recovered in undergraduate study, it is difficult for Indonesia to have a creative and innovative workforce.

Realizing that condition, the Mathematics Undergraduate Study Institut Teknologi Bandung has built a system for mathematical modeling course that is aimed to bridge students mathematical skills and the application of mathematics in solving real-world problems in Indonesia and to improve the students soft skills especially in communication and team-work capability. In this system, students work in groups of four to five students in which each group is assigned with a real-world problem to be solved. By the end of the course each group should be able to formulate a mathematical model of the assigned problem, apply mathematical skills to analyze and solve the problem, then to interpret the mathematical results and present the results. Not like in a conventional course, the mathematical modeling course is supported by a number of academic staffs which play a role as students supervisors. The students are encourage to be more active in each step of the modeling process, and mathematical modeling experiences of the supervisors can be shared to the students during the supervisions.

The unconventional approach we described above can be practiced if the system is also equipped by some other elements such as an inventory of students-workable real-world problems, an appropriate curriculum, competent academic staffs, an assessment procedure, benchmarking processes and others. This paper discusses how all elements are managed, especially on the two elements: the inventory of students-workable real-world problems and the improvement of modeling competence of academic staffs.

Most of the supervisors of mathematical modeling course at the Mathematics Undergraduate Study Institut Teknologi Bandungare actively involved in the activities of The Center for Mathematical Modeling and Simulation, Institut Teknologi Bandung, abbreviated in Indonesian as P2MS ITB. P2MS ITB is founded in 1994 and named as the Center for Research, Development and Applications of Mathematics, Institut Teknologi Bandung. In 1997 the name is changed to the present name. The aim of the center is to promote the roles of mathematics in modeling and simulation, and it tasks is to create the linkages among scientists, engineers, and industry practitioners requires a solid group in which P2MS ITB is currently, actively building this group involving local and international scientists. P2MS ITB has successfully been coordinating two research consortiums: Research Consortium on Optimization on Gas and Oil Pipeline Network (OPPINET, since 2001) and Research Consortium on Financial Modeling, Optimization & Simulation (FinanMOS, since 2008). Collaborations with national and international oil and gas, and financial companies, have been built and constantly developed through the consortiums, where P2MS ITB and the companies are hand in hand solving the problems facing by the companies. P2MS ITB also has initiated collaborations with other institutions for joint research, such as with Meteorological, Climate and Geophysical Center (BMKG) in 2013 to initiate an early warning system for disease transmission in correlation with climate factors, and other institutions.

The academic staffs which are assigned in the mathematical course are those who are active in doing industrial researches. Furthermore, they really believe that the experiences in doing industrial researches raised their interests in mathematical modeling. So that, not only limited in industrial-research activities, the staffs and P2MS ITB have been actively participating in mathematical modeling network sponsored by German Academic Exchange Service (DAAD). This network is also participated by Technische Universität Kaiserslautern, IIT Chenai, KwaZulu Natal Pietermaritzburg, University of Witwatersrand Johannesburg, to hold annual workshops, staff/student exchange, providing teaching materials or books, setting web-based platform for e-teaching, joint seminars on mathematical modeling. Besides that, P2MS ITB from 2012 collaborates with Asia Pacific Economic Cooperation (APEC) to promote a better education in mathematics via mathematical modeling activities. Through this activity, P2MS ITB has shared the mathematical modeling course system to some Indonesian universities and promoting the importance the teaching of

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mathematical modeling in secondary schools by holding a workshop on mathematical modeling in secondary schools.

For the mathematical modeling course at the Mathematics Undergraduate Study Institut Teknologi Bandung, P2MS ITB can be considered as a play ground for the academic staffs in improving the mathematical modeling competences. Besides that, it can facilitate many research and educational activities so that the system of the mathematical modeling course is continuously improved. P2MS ITB also contributes on the inventory of students-workable real-world problems since the coordinator of the mathematical modeling course encourages others supervisors in this course to providing the problems from the real-world problems that are faced by the staffs. From this situation, it will be easy for the supervisors in assisting the modeling process since they have a little bit more experiments on the problem.

Briefly, P2MS ITB has a significant role in the system of the mathematical modeling course at at the Mathematics Undergraduate Study Institut Teknologi Bandung.This kind of role and other benefits are also obtained by many mathematical departments around the world that have created or cooperated with centers for industry-university researches, for example at the University of Tennessee[[5], [15], the University of Pennsilvania[9], and Massachusetts Institute of Technology[6]. Those are just a few examples of centers for industry-university research since at U.S. National Science Foundation (NSF) Industry/University Cooperative Research Centers (IUCRC) Program solely supports about 45 centers that involve about 100 universities and about 700 firms. In successful cases, centers for industry-university researches give benefits to both industry and university. As reported in Gray and McGowen[2], universities continue to publish in high quality journals, students earn advanced degrees and develop skills that are in high demand, firms report a variety of direct and indirect benefits and center research frequently result in commercialized technologies.

In many western-countries universities which have decades history in industry-university collaborations, so that there is no longer communication gap between faculty members and industry, students can easily be involved in industry-university research projects since a very beginning of the projects. Realizing that is not the case in Indonesia, not all groups of students of the mathematical modeling course at the Mathematics Undergraduate Study Institut Teknologi Bandung directly contact with and work in industries. Up to now it is better if the course supervisors first select which problems from which collaborative projects are estimated to be appropriate for the course. If the problems have been selected, the course supervisors extract the problems into students-workable real-world problems. This paper details the problems selections and extractions. This paper also presents the result of our assessment on the course system sustainability and the student responds.

This paper is organized as follows. After this introduction, in section 2 we will discuss more about the system of the mathematical modeling course at the Mathematics Undergraduate Study Institut Teknologi Bandung.

2. The system of the mathematical modeling course at the Mathematics Undergraduate Study Institut Teknologi Bandung

If we refer to Giordano, Weir and Fox[1], the steps in mathematical modeling process are:

1) Identifying the problem,
2) Making assumptions and collect data,
3) Proposing a model,
4) Testing the assumptions,
5) Refining the model as necessary,
6) Fitting the model to real-world data if appropriate, and
7) Analyzing the underlying mathematical structure of the model to appraise the sensitivity of the conclusions when the assumptions are not precisely met.

In the convectional courses, the students are enriched by some mathematical tools and theories so that they can solve the mathematical problem. If we refer to the seven stages of mathematical modeling we describe above, the students are only trained by the fourth stage, and we cannot say that the students have an experience in solving real-world problems. For that, it is essential that the students work with realistic and authentic real-world modeling. The system of the mathematical modeling course at the Mathematics Undergraduate Study Institut Teknologi Bandung is designed so that the students can experience all seven stages of the mathematical modeling. The system consists of two essential parts: software part and hardware part, each with a number of elements in it.

The software part consists of behavior change in learning process in the mathematical modeling course, benchmarking, and assessment. The hardware part consists of academic staffs assigned as course advisors, curriculum, and the

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inventory of the real-world problems. Both parts influence each other, and each contributes to the sustainability of the system.

The system is initiated over 10 years ago by Dr. Kuntjoro A. Sidarto, a senior academic staff at the Department of Mathematics Institut Teknologi Bandung. When he started it, he was the only supervisor of the course so it was not possible for him to allow each group of students works with a different problem. By class room presentations, he introduced many problems in different areas of science and engineering where the students can learn the modeling process from it. He was one of some academic staffs that realize the need of behavior change in learning process in the mathematical modeling course, from conventional approach to unconventional approach described above. After continuous sharing the need for behavioral learning process from a conventional approach to an unconventional approach, a few other academic staffs finally accepted the idea and joined the course as supervisors.

In the beginning, the problems are chosen from books, journals, www.mathmodels.org**,** and only few problems chosen from self experiences in researches. The more academic staffs are involved in this course, the more variations of the areas of science and engineering are addresses in the course. The course coordinator then initiate to build an inventory of real-world problems that can be used by students or academic staffs in any scientific activity or in promoting mathematics.

To see the mathematical modeling competences of the students after finishing the course, the Department of Mathematics Institut Teknologi Bandung always appoints three to five group of students for participating in Mathematical Contest on Modeling and Interdisciplinary Contest in Modeling hold by Consortium on Mathematics and its Applications (COMAP) in Lexington, USA. Many reputable universities around the world participate in these contests, and the students of the Department of Mathematics Institut Teknologi Bandung showed impressive results in these contests (three meritorious awards are won).

Realizing that assessment procedure is very important in a group teaching, in the system is also equipped by an assessment procedure. This procedure must be followed by every advisor, where the coordinator will perform the final students marking.

In improving the course management, the Department of Mathematics Institut Teknologi Bandung and P2MS ITB has been actively referring to the course management having by the members of DAAD Network on Mathematical Modeling and to www.mathmodels.org.

Last important thing in this system is an appropriate empasize of mathematical modeling in the curriculum. The curriculum can be regarded as a law enforcement in order to make the system works, so that mathematical modeling and mathematical modeling competence must be explicitly mentioned as part of the curriculum in mathematics. In the last twelve years, the Department of Mathematics Institut Teknologi Bandung has reformed three curricula, the emphasize of mathematical modeling is improving. Even in the 2013 curriculum, mathematical modeling competence is explicitly written as a competence that must be had by its graduates.

3. How the mathematical modeling course is managed

As explained before, in this course students work in groups of four to five students in which each group is assigned with a real-world problem to be solved. This approach is also used in mathematical modeling courses at many universities, such as at UNSW Australia[11], Indiana University USA[7], North Carolina State University USA[8], even at United States Military Academy with its Interdisciplinary Lively Application Projects (ILAPs)[10]. By working in a group, students can improve their ability in communication and teamwork. Besides that, the problem to be solved is quite complex to be solved individually.

A number of problems are prepared by the course advisors so that each group will be assigned to a different problem. Each problem is provided in short statement and not well defined so that the students can identify the problem by themselves. This represents the situation in real-world situation in which the assignment is not provided with complete description.

To prepare the students in working in the unconventional learning process, in the first two weeks of the course the students can attend some introductory courses given by some the course supervisors. These courses discuss the mathematical modeling process in general and the course management.

In first four weeks, each group of the students will be supervised by a course supervisor so that the group can understand the problem, find detail information, talk to resources, isolating and then formulating the problem in a workable form. In the fifth week each group will present their problem in a seminar, where

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usually the students have not come up with mathematical formula of the problem. The next four week will be used by the students for formulating the problem into a (simple) mathematical model, applying their mathematical skills to find a mathematical solution and then interpreting the solution. The results are presented in the second seminar. The remaining weeks can be used for improving the model, validating the results (as necessary), elaborating the resullts and relevance to the real problems, showing the advantage and disadvantage, and presenting it in the final modeling seminar.

Any necessary data collection, contact with industry and discussion with resource persons can be done any time during the semester, after approvals from the supervisors. The complete schedule for the students and the advisors can be seen in the following table.

Table 3.1. The course schedule for the students and the advisors

Stage	Activity	Schedule
Preparation	- course advisors meeting	1 - 2 months prior to the semester
	- selection of problems	
Realization	- student groups formation	first week of the semester
	- problem assignment	first week of the semester
	- introductory course	first and second weeks of the semester
	- group discussion and supervision	along the semester
	- student presentation I	fifth week of the semester
	- student presentation II	ninth week of the semester
	- student presentation III	fourteenth week of the semester
	- data mining, contact with industry	as necessary, along the semester
Assesment and Evaluation	- student questionnaire	just after the semester
	- student report evaluation	
	- student marking	

4. The inventory of students-workable real-world problems

In ten years realization of the system, we have had a number of real-world problems that are formulated from our experiences in industry-university researches coordinated by P2MS ITB. RC OPPINET ITB contributes a large number of problems in optimization on oil and gas pipeline networks, and dealing with those problems inspired course advisors to develop similar approach in solving problems in water pipeline network and in open channel network.

In the following we present one success story on formulating a good problem for the mathematical modeling course and one story in which it leads to a failure. The others success stories and the others failures have the same factors behind it, it becomes clear what factors must be considered in formulating the problems.

2.1 Optimization Models in Oil and Gas Pipeline Network

RC OPPINET ITB has been facing many problems in optimizing oil and gas pipeline networks. One of them is a problem in distributing oil or gas through the networks so that the deliveribility of oil or gas are ensured. The problem is modeled as a mathematical optimization problem in which the deliveribity measure plays as one of its constraints. The mathematical solution are validated by the field data, which is provided by the members of RC OPPINET. The discussions with the members of RC OPPINET has encouraged the researchers of RC OPPINET to try many solutions methods in order to have the most efficient method for solving the problem. We see that the optimization problem can be easily applied to any oil or gas pipeline network with a small adjusment. The valuable comments from the members of RC OPPINET and the experiences in RC OPPINET made the course advisors can formulate some simplified problems for the course.

2.2 Flow Assurance Model in Water Pipeline Network

The problem on flow assurance in Water Pipeline Network is provided as a problem at the mathematical modeling course in year 2009. The problem is inspired by the similar problem in oil and gas pipeline network, in which RC OPPINET ITB has successfully derived and solved the model even a user-friendly software has been built based on the model. Another thing that inspired the course advisors to provide this problem is the fact that the Authority of Water Distribution of Bandung has been facing a serious problem in water loss. An agreement with the top management of the authority has been build, but then we had some difficulties in collecting data since up to the end of semester we did not have a right counterpart at the authority office.

2.3 Key Factors for formulating a good problem

In Table 4.3.1 below, we list some factors that must be considered in formulating the problems so that it will be the students-workable problems. We recognize that factors numbers 1, 4, and 5 are necessary, while at least one of factors numbers 2 and 3 is necessary.

Table 4.3.1. Factors that must be considered in formulating the problems

No	Factor
1.	There are some references at the library or in internet
2.	There is at least course advisor that understand the problem
3.	There is at least one resource person who work on it in daily basis
4.	Data for validation is available
5.	Can be formulated/simplified so that mathematicsl skills of the students are sufficient

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2.4 The inventory

We have been documenting the problems in form of final reports of the students works. Some problems are studied further by some students in their undergraduate final projects. Some are even studied further at graduate studies. The inventory also helps the academic staffs, students, and alumni in promoting mathematics. An alumnus who has working at a company came to an author for discussing a problem she heard at the presentation (she did not work with the problem), in which she thought the problem was similar to a problem facing by her company.

5. Sustainability of the system of the mathematical modeling course

The system of the mathematical course we discuss in this paper is one system which is so easy to lead to a failure unless there are some good practices in maintaining and improving it. In Institut Teknologi Bandung, teaching around 100 of students can be managed in two conventional classes which just need two lecturers. With the same number of students, the mathematical modeling course needs a large number of advisors, so if we compare to conventional approach the system needs four to five more number of lecturers. Sharing the idea to other academic staffs which have not been involved in this course is a key factor to have sufficient number of advisors.

The table below shows a comparison of the mathematical modeling course in 2004 and in 2014.

Table 5.1. The mathematical modeling course in 2004 and in 2014.

Item	Year 2004	Year 2014
Number of students	100	110
Number of academic staffs involved	6	14
Number of resource persons from industries	5 (Yogya Supermarket, Dept of Civil Engineering, Dept of Biology, RC OPPINET, Eijckman Research Institut)	6 (RC OPPINET, Pertamina Retail, BMKG, APEC, Eijckman Research Institut Dept of Chemistry)
Number of problems extracted from industrial projects	6	9
Benchmarking	- MCM/ICM held by COMAP, Lexington, USA	- MCM/ICM held by COMAP, Lexington, USA
Cooperative activities related to the course		- DAAD Network (since 2009)
		- APEC (2012)
		- Industrial Math Week

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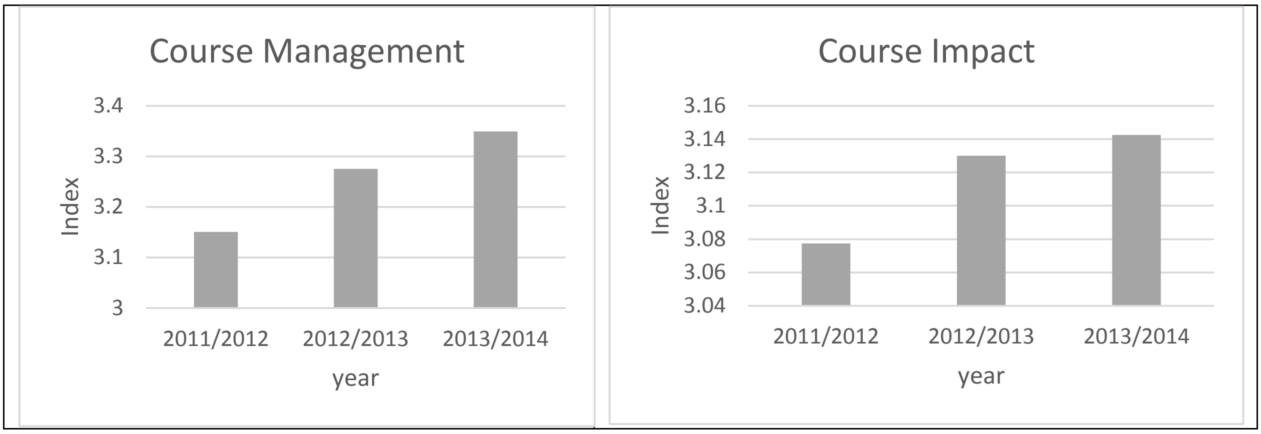
In Table 5.1 we can see that in ten years the number of course advisors and the number of problems extracted from industrial projects are increased. This shows that the system is sustained, and is tried to be improved where the list of cooperative activities related to the course shown in the table is one of its parameter.

But the increasing number of course advisors should be treated carefully. This shows that there are more academic staffs that realize the benefit of participating in the mathematic modeling course, but it seems not so easy change the behavior from the conventional approach in teaching to the unconventional approach as needed in this course.

We analyzes last three years data related to this course from the ITB students questionnaires, which we present in Figure 5.1 below. In this last three years, the students perception indices to the course management and the course impact are increasing (index value is in the interval [0,4]). But in the academic year 2013/2014, when the course coordinator invited four new course advisors, the advisors competences and the advisors commitments are little bit lower than for the academic years 2011/2012 and 2012/2013. This means that course coordination must be done carefully if we decide to involve more and more academic staffs as course advisors.



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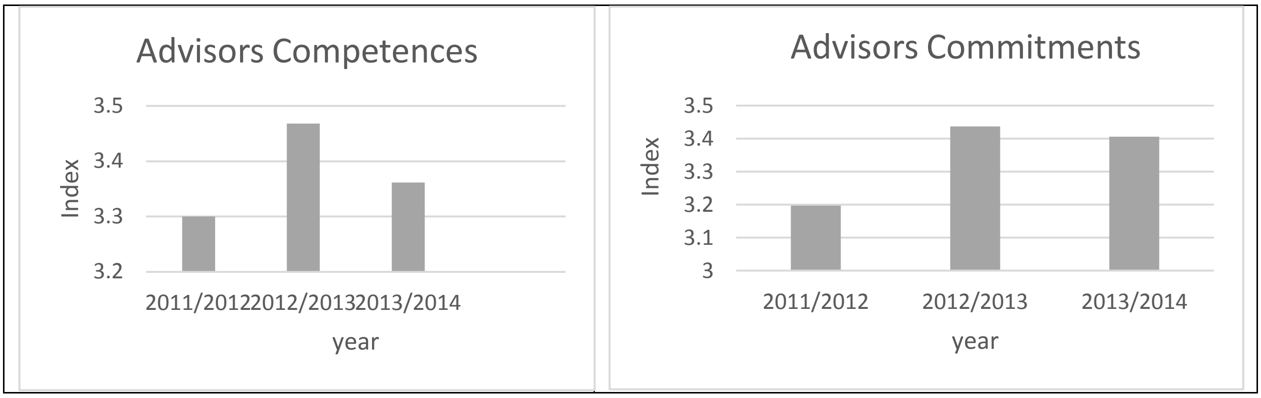

Figure 5.1.

To see the course impact , we collect data from the students questioning their impressions and what kind skills that they learn from the course.

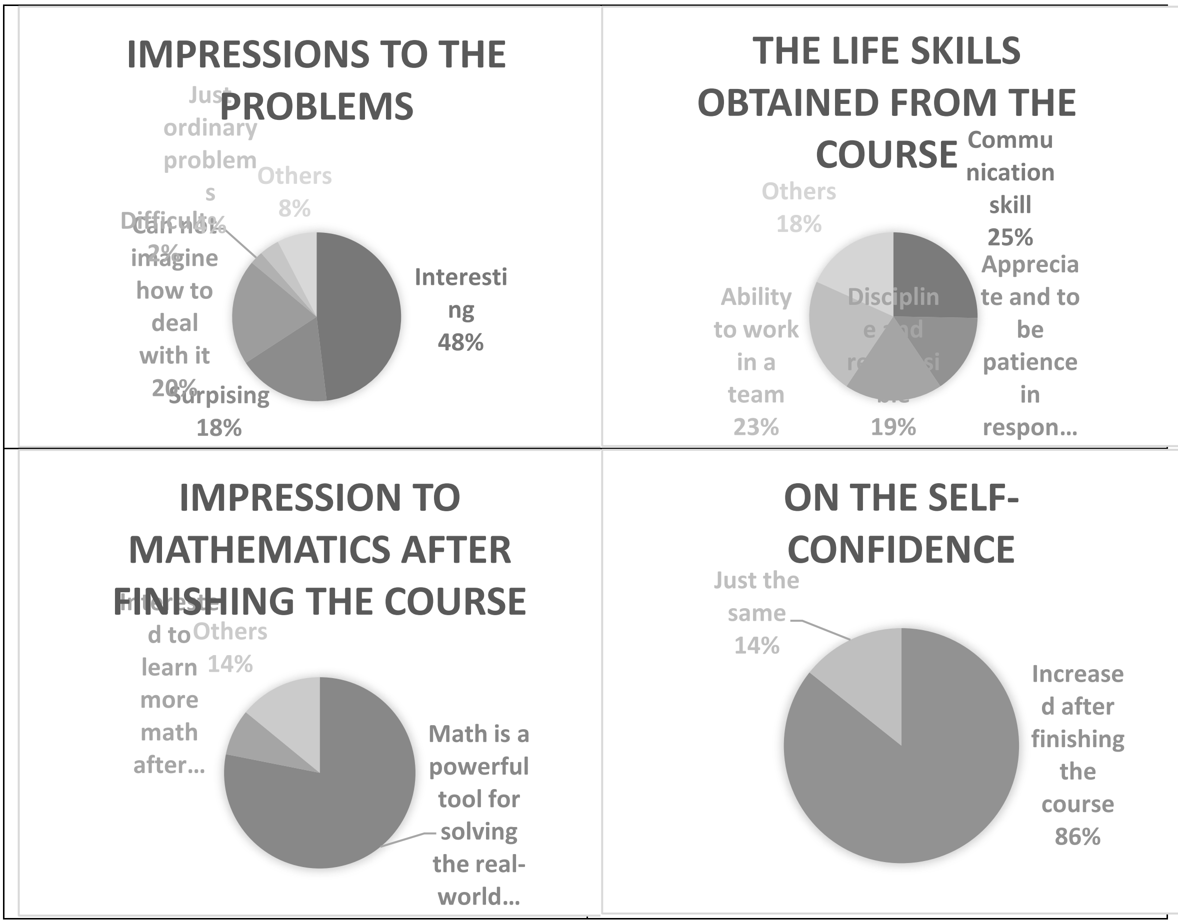

Figure 5.2. The results of the students questionnaire

The top-left chart in Figure 5.2 above shows that in general the course advisors have chosen interesting problems to be solve during the course, and the experiences that are obtained by the students have increased their motivation in learning mathematics and also have increased their life-skills as shown by the others charts.

6. Conclusion

The system of mathematical modeling course at the Department of Mathematics, Institut Teknologi Bandung, is designed to train students in mathematical modeling process of real-world problems, which allows the students work with real-world problems. Working real-world problems does not mean we just send the students to industries where any effective communication between industry and the Department has not been obtained. In order to make the system sustain, all elements in the system must be maintained and be improved. One essential element is the inventory of students-workable real-world problems, which can be maintained by continuous industry-university researches where the course supervisors should be actively involved in these researches. P2MS ITB has successfully conducting a number of industry-university researches, and one of the benefits of the researches is to the maintenance and improvement of the inventory of students-workable real-world problems.

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