Program Learning Outcomes Level Achievement in the Mathematics and Basic Sciences Group Course

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Abstract. The Program Learning Outcomes (PLO) is the expected achievement at the level of knowledge, skills and essential abilities of each student after they graduate. The Mechanical Engineering study program, Faculty of Engineering, Universitas Negeri Surabaya has formulated 10 PLO study programs that students must achieve through all designed courses. Measurement of PLO achievement is carried out through several assessments including participation, assignments, midterm exams and semester final exams. This study resulted in the calculation of PLO achievement, especially in PLO 1, PLO 3, and PLO 4 based on 4 basic courses, namely mathematics 1, physics 1, basic chemistry, and Life Sciences which were held in semester 1 of the 2019/2020 academic year. PLO achievement analysis, namely PLO 1, PLO 3 and PLO 4, has been carried out in 4 basic courses, namely mathematics 1, physics 1, basic chemistry, and life sciences, in 12 classes in the Mechanical Engineering S-1 study program for the 2019/2020 school year. The results of the analysis show that 95% of students have met the PLO achievement standards of the study program. The highest percentage results were obtained in the "Good" level category, followed in order from top to bottom, namely "Very Satisfy", "Very Good", "Satisfy" and "Excellent" levels. Based on these gains, it is known that most students are able to make prototypes, but few are able to develop the prototype, while regarding PLO 4, it can be seen that most students are able to analyse the application of 75% of problem solutions, but few are able to convey the solution to an engineering problem.

Keywords: Program Learning Outcomes · OBE · Mechanical Engineering Program

1 Introduction

Universitas Negeri Surabaya always follows the development of the world of education and industry. One of the efforts is to direct the study program to be able to obtain international accreditation predicate. This is a manifestation of the achievement of the university's vision and mission as well as Unesa and Kemendikbudristek Dikti performance targets, as well as strategic target indicators in the Unesa Strategic Plan.

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Table 1. Program Learning Outcomes (PLO) of the Mechanical Engineering

No.	PLO
1	Science and Engineering Knowledge
2	Design and Development of Environmental and Sustainability Concerned Solutions
3	Experiment and Data Analysis
4	Problem analysis
5	Introduction to Modern Equipment
6	Communication
7	Project and Cost Management
8	Work independently and in groups
9	Engineering and Professional Ethics
10	Lifelong Learning

The implementation of OBE in the education system of the Mechanical Engineering undergraduate study program, Faculty of Engineering, Unesa has been carried out. The PEO and PLO formulations of the Mechanical Engineering Study Program have also been formed, and an analysis of the achievement of the determined PLO needs to be carried out continuously in order to determine the steps for continuous improvement, both improvements at the level of curriculum implementation and (if necessary) curriculum revision. The learning outcomes of the Mechanical Engineering study program are presented in Table 1.

This study aims to analyse the achievement of the PLO that has been determined in the Mechanical Engineering S-1 study program, Faculty of Engineering, UNESA. The PLO measurement model used is the Provus Discrepancy Evaluation, namely by comparing the PLO achievements evaluated against the PLO standards that have been set. The gap between quality performance and standards is a consideration for making modifications. Modifications are made to performance that is not in accordance with predetermined standards, or it can be modified standards if performance has exceeded it. Furthermore, it is decided whether improvements are made to the quality performance or standards, or the quality performance is considered complete in the evaluation process. Improvements in quality performance can be made through improving learning methods.

2 Method

Analysis of PLO achievement, namely PLO 1, PLO 3 and PLO 4, has been carried out on 4 basic courses, of 12 classes in the Mechanical Engineering undergraduate study program in the academic year 2019/2020. The assessment is carried out through the final grades of students obtained based on the distribution and weighting matrix on the PLO by each lecturer in charge of the course.

The assessment of PLO is carried out by taking courses in the odd semester of the 2019/2020 school year, in the Mathematics and Basic Sciences group based

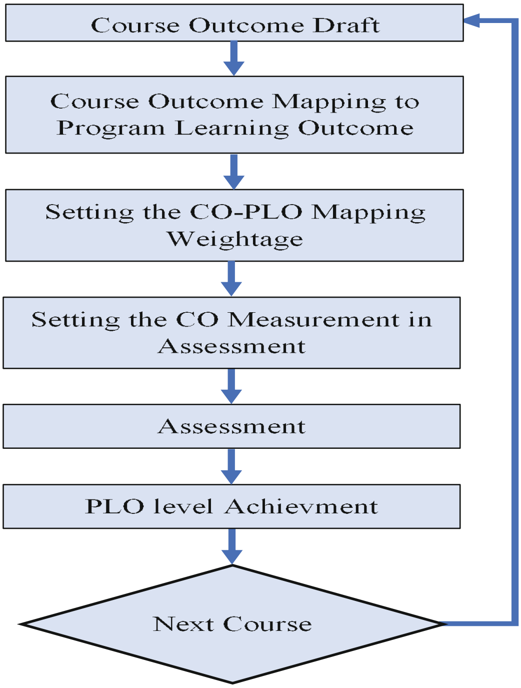


Fig. 1. Stage assessment scheme

on the BKSTM. BKSTM is The Indonesian Mechanical Engineering Cooperation Agency, an organization formed at a meeting of the heads of the department/study program/department of Mechanical Engineering universities throughout Indonesia. The courses based on BKSTM Mathematics and Basic Sciences group that used in this research are: Basic chemistry, Physics 1, Mathematics 1, and Life Science Course.

Several stages were carried out related to the PLO assessment, including: (1) Course Outcome Draft, (2) Course Outcomes Mapping to Program Learning Outcomes, (3) Setting the CO-PLO Mapping Weightage, (4) Setting the CO measurement in assessment, (5) Assessment, and (6) PLO Level Achievement.

Figure 1 depicts the steps before program results can be measured and calculated. It is important to determine how you want to evaluate the outcome of the course. This should be specific about the number of questions on the test as well as any related assignments and projects. The level of achievement must also be determined and agreed upon among program members so that everyone has the same standard of reference.

3 Result and Discussion

3.1 Course Outcomes Mapping to Program Learning Outcomes

The courses that used in this research are: Basic chemistry, Physics 1, Mathematics 1, and Life Science Course. The determination of the PLO supporting courses can be seen in the course matrix table against the PLO which is presented in Table 2.

Table 2. Course matrix against PLO

No	Courses	PLO									
		1	2	3	4	5	6	7	8	9	10
1	Mathematics 1	√		√	√						
2	Physics 1	√		√	√						
3	Basic Chemistry	√		√	√						
4	Life Science	√		√	√						

Table 3. Basic Chemistry Course Outcomes (CO)

CO-1	Demonstrate an understanding of chemistry and be able to explain the general principles, laws, and theories of chemistry
CO-2	Be able to Use critical thinking and logic in the solution of chemistry problems
CO-3	Apply learned chemistry skills to analyse new issue

Each subject has its own course outcomes. The course outcomes are contained in each semester learning plan. It can be seen how the sub-Course outcomes which are derivatives of the outcomes of each course in the semester learning plan.

Course Outcomes are specified for each course. Basic chemistry, Physics 1, Mathematics 1, and Life Science.

Course, each have 3 course outcomes, and in this case, course outcomes from basic chemistry courses are taken as examples to show how the distribution of weight of score taken to be able to calculate the value of PLO.

There are three associated course outcomes as decided by the instructor for Basic Chemistry, it could be shown at Table 3.

The next stage is the correlation of the Course Outcomes (CO) of each course to the PLO of the study program. The correlation is presented in Table 4.

After the correlation between the CO of the course and the PLO of the study program, the next step is to determine the evaluation weights used in the calculation. The determination of the weights is carried out by each lecturer for the subjects taught. In the following, the basic chemistry course is taken as an example of a calculation, where the calculation is also carried out in other courses, so that the PLO value achieved is obtained. The weighting of basic chemistry courses can be observed in the Table 5. While the total weights that contribute to the calculation of each PLO are shown in

Table 4. Correlation of CO courses to PLO

Courses		PLO		
		1	3	4
Mathematics 1	CO 1	√		
	CO 2		√	
	CO 3			√
Physics 1	CO 1	√		
	CO 2		√	
	CO 3			√
Basic Chemistry	CO 1	√		
	CO 2		√	
	CO 3			√
Life Science	CO 1	√		
	CO 2		√	
	CO 3			√

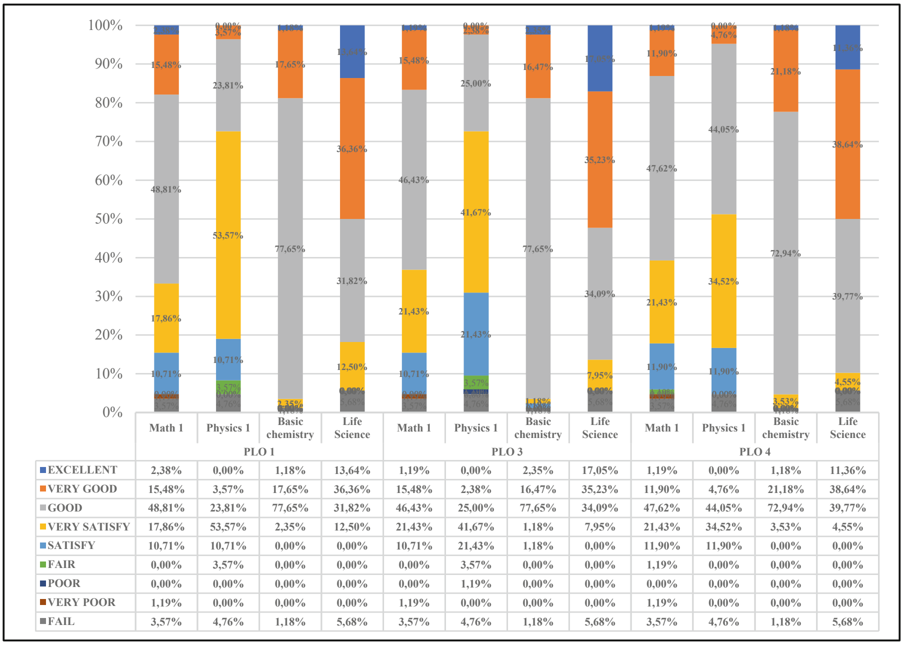
Table 5. Weight of ability test items for basic chemistry courses

Assesment	Weight	PLO 1	PLO 3	PLO 4
		CO-1	CO-2	CO-3
Participation	**20%**	40%	30%	30%
Assignment	**30%**	20%	40%	40%
Midterm exams	**20%**	25%	45%	30%
Final exams	**30%**	30%	50%	20%

The distribution of the percentage weighting on the sub-CO that has been compiled through the Semester Lecture Plan and the assessment carried out for 1 Semester. An example of an assessment tool and a description of the distribution of the weights in the assessment plan is described in the Semester Lecture Plan of the course and specific for each course.

3.2 PLO Achievement

The Rubric for Each Category of Achievement of PLO 1, 3 and 4 Can be Seen in The PLO achievement standard for study programs is a minimum of 'Fair'. Based on the evaluation of PLO achievement, it can be observed that 95% on average meet the PLO achievement standards of the study program, which is at least at the satisfy level, while 4.3%–5.29% of students are declared. The percentage of failures was due to the fact that students did not take the exam, either assignments, UTS, or UAS.



	PLO 1				PLO 3				PLO 4			
	Math 1	Physics 1	Basic chemistry	Life Science	Math 1	Physics 1	Basic chemistry	Life Science	Math 1	Physics 1	Basic chemistry	Life Science
EXCELLENT	2,38%	0,00%	1,18%	13,64%	1,19%	0,00%	2,35%	17,05%	1,19%	0,00%	1,18%	11,36%
VERY GOOD	15,48%	3,57%	17,65%	36,36%	15,48%	2,38%	16,47%	35,23%	11,90%	4,76%	21,18%	38,64%
GOOD	48,81%	23,81%	77,65%	31,82%	46,43%	25,00%	77,65%	34,09%	47,62%	44,05%	72,94%	39,77%
VERY SATISFY	17,86%	53,57%	2,35%	12,50%	21,43%	41,67%	1,18%	7,95%	21,43%	34,52%	3,53%	4,55%
SATISFY	10,71%	10,71%	0,00%	0,00%	10,71%	21,43%	1,18%	0,00%	11,90%	11,90%	0,00%	0,00%
FAIR	0,00%	3,57%	0,00%	0,00%	0,00%	3,57%	0,00%	0,00%	1,19%	0,00%	0,00%	0,00%
POOR	0,00%	0,00%	0,00%	0,00%	0,00%	1,19%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
VERY POOR	1,19%	0,00%	0,00%	0,00%	1,19%	0,00%	0,00%	0,00%	1,19%	0,00%	0,00%	0,00%
FAIL	3,57%	4,76%	1,18%	5,68%	3,57%	4,76%	1,18%	5,68%	3,57%	4,76%	1,18%	5,68%

Fig. 2. PLO 1, 3, and 4 percentage recapitulation graph in 4 basic courses

Refer to the graph on, it can also be observed that the largest percentage of PLO 1, 3 and 4 achievements are in the "Good" category, namely at a percentage of 45.5%–51.1%, followed by a "very satisfy" level of 16.01%–21.57%, then the "very good" level is 17.39%–19.12%, then the 'satisfy' level is 5.36%–8.33%, and 'excellent' level in percentage 3.43%–4.30%. Based on this percentage, it can be observed that related to PLO 1, most students have been able to model 90% of real conditions, but few are able to demonstrate 75% of the facts from the modelling results. Related to PLO 3, it is known that most students are able to make prototypes, but few are able to develop the prototype, while related to PLO 4, it can be seen that most students are able to analyse the application of 75% of problem solutions, but few are able to convey the solution to an engineering problem (Fig. 2).

3.3 Proposed Improvements

Based on the PLO achievement analysis, some suggestions for corrective actions include:

- Applying active learning methods in lectures
- Collaborate with majors in mathematics, chemistry, biology and physics, in project courses and in assessments
- Applying modern tools in lectures
- Increase the number of laboratories to conduct experiments and increase the experimental section and study laboratory work

- Improve students' ability to analyze and describe the results of measurements and experiments.
- Carry out independent work reports, projects, and course assignments according to a predetermined format then evaluate the results.
- To assess the ability to write reports correctly and well for the purpose of developing these skills.
- Acquire methodologies for using books and literature related to assignments and retrieving citations according to standards
- Connecting project themes to real practical problems
- Build a team-friendly learning environment for project idea generation and solution creation.
- Use modern software and tools to design projects and evaluate results (Tables 6, 7 and 8).

Table 6. Weight Distribution in Sub-CO Basic Chemistry Course

			WEIGHT AGAINST PLO			TOTAL	TOTAL WEIGHT			Total
	Appraisal Form	Value Weight	PLO 1	PLO 3	PLO 4		PLO 1	PLO 3	PLO 4	
			CO-1	CO-2	CO-3		CO-1	CO-2	CO-3	
Sub CO-1 Understanding the Chemistry in Context, Classification of Matter and Chemical Properties	**Participation**					0.0	0.00	0.00	0.00	0.00
	Assignment	0.05	0.20	0.40	0.40	1.0	0.01	0.02	0.02	0.05
	Midterm Exam					0.0	0.00	0.00	0.00	0.00
	Final Exam					0.0	0.00	0.00	0.00	0.00
Sub CO-2 Understanding The Atoms Structure, Molecules, and Ions	**Participation**	0.10	0.40	0.30	0.30	1.0	0.04	0.03	0.03	0.10
	Assignment					0.0	0.00	0.00	0.00	0.00
	Midterm Exam					0.0	0.00	0.00	0.00	0.00
	Final Exam					0.0	0.00	0.00	0.00	0.00
Sub CO-3 Understanding The Periodic Table	**Participation**					0.0	0.00	0.00	0.00	0.00
	Assignment					0.0	0.00	0.00	0.00	0.00
	Midterm Exam	0.10	0.25	0.45	0.30	1.0	0.03	0.05	0.03	0.10
	Final Exam					0.0	0.00	0.00	0.00	0.00

(*continued*)

Table 6. (*continued*)

			WEIGHT AGAINST PLO			TOTAL	TOTAL WEIGHT			Total
	Appraisal Form	Value Weight	PLO 1	PLO 3	PLO 4		PLO 1	PLO 3	PLO 4	
			CO-1	CO-2	CO-3		CO-1	CO-2	CO-3	
Sub CO-4 Chemical Bonding and Molecular Geometry	**Participation**					0.0	0.00	0.00	0.00	0.00
	Assignment					0.0	0.00	0.00	0.00	0.00
	Midterm Exam	0.10	0.25	0.45	0.30	1.0	0.03	0.05	0.03	0.10
	Final Exam					0.0	0.00	0.00	0.00	0.00
Sub CO-5 Understanding The Composition of Substances and Solutions	**Participation**					0.0	0.00	0.00	0.00	0.00
	Assignment	0.05	0.20	0.40	0.40	1.0	0.01	0.02	0.02	0.05
	Midterm Exam					0.0	0.00	0.00	0.00	0.00
	Final Exam					0.0	0.00	0.00	0.00	0.00
Sub CO-6 Understanding The Stoichiometry of Chemical Reactions	**Participation**					0.0	0.00	0.00	0.00	0.00
	Assignment	0.10	0.20	0.40	0.40	1.0	0.02	0.04	0.04	0.10
	Midterm Exam					0.0	0.00	0.00	0.00	0.00
	Final Exam					0.0	0.00	0.00	0.00	0.00
Sub CO-7 Understanding The Electrochemistry	**Participation**					0.0	0.00	0.00	0.00	0.00
	Assignment					0.0	0.00	0.00	0.00	0.00
	Midterm Exam					0.0	0.00	0.00	0.00	0.00
	Final Exam	0.10	0.30	0.50	0.20	1.0	0.03	0.05	0.02	0.10
Sub CO-8 Understanding The Entropy and the Second Law of Thermodynamics	**Participation**	0.10	0.40	0.30	0.30	1.0	0.04	0.03	0.03	0.10
	Assignment					0.0	0.00	0.00	0.00	0.00
	Midterm Exam					0.0	0.00	0.00	0.00	0.00
	Final Exam					0.0	0.00	0.00	0.00	0.00
Sub CO-9 Understanding Thermochemistry	**Participation**					0.0	0.00	0.00	0.00	0.00
	Assignment	0.05	0.20	0.40	0.40	1.0	0.01	0.02	0.02	0.05
	Midterm Exam					0.0	0.00	0.00	0.00	0.00
	Final Exam					0.0	0.00	0.00	0.00	0.00
Sub CO-10 Understanding the Chemical Kinetics	**Participation**					0.0	0.00	0.00	0.00	0.00
	Assignment	0.05	0.20	0.40	0.40	1.0	0.01	0.02	0.02	0.05
	Midterm Exam					0.0	0.00	0.00	0.00	0.00
	Final Exam					0.0	0.00	0.00	0.00	0.00

(*continued*)

Table 6. (*continued*)

			WEIGHT AGAINST PLO			TOTAL	TOTAL WEIGHT			Total
	Appraisal Form	Value Weight	PLO 1	PLO 3	PLO 4		PLO 1	PLO 3	PLO 4	
			CO-1	CO-2	CO-3		CO-1	CO-2	CO-3	
Sub CO-12 Understanding the Nuclear Chemistry	**Participation**					0.0	0.00	0.00	0.00	0.00
	Assignment					0.0	0.00	0.00	0.00	0.00
	Midterm Exam					0.0	0.00	0.00	0.00	0.00
	Final Exam	0.10	0.30	0.50	0.20	1.0	0.03	0.05	0.02	0.10
TOTAL	**1.00**				**12.0**				**1.00**	

Table 7. Total PLO weight

Assessments	Score Weight	PLO 1	PLO 3	PLO 4	Total	PLO 1	PLO 3	PLO 4	Total
		CO-1	CO-2	CO-3		CO-1	CO-2	CO-3	
Participation	0.20	0.40	0.30	0.30	1.00	0.08	0.06	0.06	0.20
Assignment	0.30	0.20	0.40	0.40	1.00	0.06	0.12	0.12	0.30
Midterm exams	0.20	0.25	0.45	0.30	1.00	0.05	0.09	0.06	0.20
Final exams	0.30	0.30	0.50	0.20	1.00	0.09	0.15	0.06	0.30
	1.00	1.15	1.65	1.20	4.00	0.28	0.42	0.30	1.00

Table 8. PLO-1, -2, and -3 Rubrics

Criteria	PLO-1	PLO-3	PLO-4
Excellent	Able to demonstrate 75% facts from modeling results	Able to develop prototype	Able to present problem solutions
Very Good	Able to demonstrate 50% facts from modeling results	Able to analyze prototype performance	Able to analyze the application of 90% of problem solutions
Good	Able to model 90% of real conditions	Able to make prototypes	Able to analyze the application of 75% of problem solutions
Very Satisfy	Able to model 75% real conditions	Able to produce solution needs	Able to find 90% solutions to problems

(*continued*)

Table 8. (*continued*)

Criteria	PLO-1	PLO-3	PLO-4
Satisfy	Able to model 50% of real conditions	Able to set appropriate criteria in solution evaluation	Able to find 75% solution to problems
Fair	Able to identify science and engineering knowledge by 90%	Able to identify solution evaluation	Able to find 50% solution to the problem
Poor	Able to identify knowledge of science and engineering by 75%	Able to analyze problems	Able to formulate problems
Very Poor	Able to identify science and engineering knowledge by 50%	Able to identify problems	Able to identify problems
File	Unable to identify knowledge of science and engineering	Unable to identify the problem	Unable to identify the problem

4 Conclusion

The achievement of PLO 1, PLO 3 and PLO 4, has been carried out on 4 basic courses, namely mathematics 1, physics 1, basic chemistry, and life sciences, in 12 classes in the Mechanical Engineering undergraduate study program in the academic year 2019/2020. The results of the analysis show that 95% of students have met the PLO achievement standards of the study program. The highest percentage results were obtained in the "Good" level category, followed in a row from top to bottom, namely "Very Satisfy", "Very Good", 'Satisfy" and "Excellent" levels. Based on these acquisitions, then it is known that most of the students are able to make prototypes, but few are able to develop the prototype, while regarding PLO 4, it can be seen that most of the students are able to analyse the application of 75% of problem solutions, but few are able to convey the solution to an engineering problem.

Suggestions for improvement based on the PLO achievement analysis are changing the teaching method of lecturers, namely increasing project activities and preparing project reports, thereby increasing students' understanding abilities in designing settlement methodologies, evaluations and skills in providing solutions to problems.

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Endah; draft manuscript preparation: Arsana. I Made. All authors reviewed the results and approved the final version of the manuscript.

Bibliography

1. E.M. Clarke, E.A. Emerson, Design and synthesis of synchronization skeletons using branching time temporal logic, in: D. Kozen (Eds.), Workshop on Logics of Programs, Lecture Notes in Computer Science, vol. 131, Springer, Berlin, Heidelberg, 1981, pp. 52–71. DOI: https://doi.org/10.1007/BFb0025774
2. J.P. Queille, J. Sifakis, Specification and verification of concurrent systems in CESAR, in: M. Dezani-Ciancaglini and U. Montanari (Eds.), Proceedings of the 5th International Symposium on Programming, Lecture Notes in Computer Science, vol. 137, Springer, Berlin, Heidelberg, 1982, pp. 337–351. DOI: https://doi.org/10.1007/3-540-11494-7_22
3. C. Baier, J-P. Katoen, Principles of Model Checking, MIT Press, 2008.
4. M. Kwiatkowska, G. Norman, D. Parker, Stochastic model checking, in: M. Bernardo, J. Hillston (Eds.), Proceedings of the Formal Methods for the Design of Computer, Communication and Software Systems: Performance Evaluation (SFM), Springer, Berlin, Heidelberg, 2007, pp. 220–270. DOI: https://doi.org/10.1007/978-3-540-72522-0_6
5. V. Forejt, M. Kwiatkowska, G. Norman, D. Parker, Automated verification techniques for probabilistic systems, in: M. Bernardo, V. Issarny (Eds.), Proceedings of the Formal Methods for Eternal Networked Software Systems (SFM), Springer, Berlin, Heidelberg, 2011, pp. 53–113. DOI: https://doi.org/10.1007/978-3-642-21455-4_3
6. G.D. Penna, B. Intrigila, I. Melatti, E. Tronci, M.V. Zilli, Bounded probabilistic model checking with the muralpha verifier, in: A.J. Hu, A.K. Martin (Eds.), Proceedings of the Formal Methods in Computer-Aided Design, Springer, Berlin, Heidelberg, 2004, pp. 214–229. DOI: https://doi.org/10.1007/978-3-540-30494-4_16
7. E. Clarke, O. Grumberg, S. Jha, et al., Counterexample-guided abstraction refinement, in: E.A. Emerson, A.P. Sistla (Eds.), Computer Aided Verification, Springer, Berlin, Heidelberg, 2000, pp. 154–169. DOI: https://doi.org/10.1007/10722167_15
8. H. Barringer, R. Kuiper, A. Pnueli, Now you may compose temporal logic specifications, in: Proceedings of the Sixteenth Annual ACM Symposium on the Theory of Computing (STOC), ACM, 1984, pp. 51–63. DOI: https://doi.org/10.1145/800057.808665
9. A. Pnueli, In transition from global to modular temporal reasoning about programs, in: K.R. Apt (Ed.), Logics and Models of Concurrent Systems, Springer, Berlin, Heidelberg, 1984, pp. 123–144. DOI: https://doi.org/10.1007/978-3-642-82453-1_5
10. B. Meyer, Applying “Design by Contract”, Computer 25(10) (1992) 40–51. DOI: https://doi.org/10.1109/2.161279
11. S. Bensalem, M. Bogza, A. Legay, T.H. Nguyen, J. Sifakis, R. Yan, Incremental component-based construction and verification using invariants, in: Proceedings of the Conference on Formal Methods in Computer Aided Design (FMCAD), IEEE Press, Piscataway, NJ, 2010, pp. 257–256.
12. H. Barringer, C.S. Pasareanu, D. Giannakopolou, Proof rules for automated compositional verification through learning, in Proc. of the 2nd International Workshop on Specification and Verification of Component Based Systems, 2003.
13. M.G. Bobaru, C.S. Pasareanu, D. Giannakopoulou, Automated assume-guarantee reasoning by abstraction refinement, in: A. Gupta, S. Malik (Eds.), Proceedings of the Computer Aided Verification, Springer, Berlin, Heidelberg, 2008, pp. 135–148. DOI: https://doi.org/10.1007/978-3-540-70545-1_14