

PAPER • OPEN ACCESS

Developing project based learning module of CNC milling mechanical technique on mechanical engineering department vocational high schools in Surakarta

To cite this article: T U Nugroho and T Sukardi 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **535** 012027

View the [article online](#) for updates and enhancements.

Developing project based learning module of CNC milling mechanical technique on mechanical engineering department vocational high schools in Surakarta

T U Nugroho¹ and T Sukardi²

^{1,2} Technology and Vocational Education, Postgraduate of Yogyakarta State University, Yogyakarta, Indonesia

E-mail: triujann@gmail.com

Abstract. This development research that use ADDIE model with stages: (1) Analysis, (2) Design, (3) Development, (4) Implementation, and (5) Evaluation. The object of research was students of XII class on Vocational High Schools in Surakarta. Internal trials included validation material expert and media expert, while external trials included teachers and students responses to use module. The trials data was collected through questionnaire, observation, documentation, and interview which were analyzed qualitatively and quantitatively. The research result: (1) The CNC learning module developed is suitable for CNC learning, students can learn independently and thoroughly, includes description and CNC learning goals, adapted to development of science and technology, students easy to read and understand; (2) CNC learning module developed were declared very feasible by material expert feasibility percentage of 83.2% and media expert feasibility percentage of 84.04%, the teachers response to the module is 95.6% and the students response is 85.8% which module is very suitable to be used; (3) increasing of students learning outcome after using the module is 17.09% and student learning completeness reaches 100%. The conclusion of research results is module very feasible and effective to be used for CNC learning at Vocational High Schools in Surakarta.

1. Introduction

The current of globalization is changing lifestyle of society from traditional agrarian to modern industry. Indonesia participation in Trends in International Mathematics and Science Study (TIMSS) and Program for International Student Assessment (PISA) since 1999 to show that the achievement of Indonesian childrens are not so good. This is because the number of test materials in TIMSS and PISA is not found in the education curriculum in Indonesia [1]. The loss of Indonesia in the education sector has encouraged the government to organize and develop an international standard education unit at all level of education. The path of education held in Indonesia consists of formal, nonformal, and informal education. The formal education level consists of basic education, secondary education, and higher education, while the types of education composed general education, professional and vocational education, religious education, and special education [2].

Vocational High School is held to improve intelligence, knowledge, personality, noble character, and skills of students to live independently and follow further education in accordance with their vocational program [3]. In order to work optimally, they must have strong stamina, master the basic of



science and technology, have a high work ethic, be able to communicate according to work demand, and have the ability to develop themselves. Vocational High Schools emphasize that graduates have competencies that are in accordance with their field of expertise, for example in the Mechanical Engineering Department, one of the competencies that must be mastered by students is Computer Numerical Control (CNC). This competency is very important, because many industries now use CNC on based production machines to achieve higher productivity. Competency standard in CNC Machining Technique is to require students to master three competency standards, that is setting NC/CNC machine, programming NC/CNC machine, and operating NC/CNC machine [4].

CNC Learning for Vocational High Schools has not been able to be implemented in accordance with the applicable curriculum objectives, due to the lack of details of competency achievement indicators in core competencies and basic competencies, and the limited facilities and infrastructure owned by Vocational High Schools. As a comparison of ratio the number of CNC machines to the number of practicum at Vocational High Schools in Surakarta, where one CNC machine is used for 10-20 students. Based on data from the Student Skills Competition in Surakarta on 2017 for CNC competition, there are only three participants, that is State Vocational High School 2, St. Mikael Vocational High School, and Warga Vocational High School [5], whereas in Surakarta there are around 12 Vocational High Schools that have Mechanical Engineering Department. The low participation of Vocational High Schools participating in Student Skills Competition is due to the lack of ability of Vocational High Schools to prepare CNC machining competency, both in terms of teaching materials, learning component, and infrastructure facilities.

The CNC learning process at Vocational High Schools in Surakarta which includes material, learning strategies, infrastructure, and learning schedules is not sufficient to achieve student competency, due to the absence of standard CNC learning processes for students. The Learning Implementation Plan made by the teacher still refers to the cognitive or theoretical domain, while in the psychomotor domain or practice there is still less. In learning CNC, a teacher who is competent and able to teach the material thoroughly to students is needed to master all CNC competencies taught [6]. However, there are still many teachers who are not yet competent, such as not being able to operate CNC machine in their schools and the low ability of teachers to use computer software as a simulation media and CNC programming. In addition, it is also due to the lack of teaching materials and learning media that students can use for independent learning, such as module and CNC simulator. Therefore, it is necessary to do research on the Development Learning Module of CNC Milling Machining Technique with the help of CAD/CAM software that achieves through Project Based Learning in the Mechanical Engineering Department at Vocational High Schools in Surakarta.

Table 1. Data Analysis of CNC Learning Observation at Vocational High Schools in Surakarta

Nu.	Vocational Name	Curriculum	CNC Module	Number of CNC	Simulation Machines
1	SMK Negeri 2	2013 Curriculum	√	12	Mastercam
2	SMK Negeri 5	2013 Curriculum	√	11	Mastercam
3	SMK Bhineka Karya	KTSP	-	2	Mastercam
4	SMK Kristen 2	KTSP	√	3	Mastercam
5	SMK Muhammadiyah 1	2013 Curriculum	-	1	Mastercam
6	SMK Murni 1	KTSP	-	1	-
7	SMK Pancasila	2013 Curriculum	-	2	Mastercam
8	SMK PGRI 1	2013 Curriculum	-	2	Mastercam
9	SMK St. Mikael	KTSP	√	8	Mastercam
10	SMK Tunas Pembangunan 2	KTSP	-	1	-
11	SMK Tunas Pembangunan 3	KTSP	-	-	-
12	SMK Warga	2013 Curriculum	√	13	Mastercam

Learning activities require teaching materials as the delivery of material to students. One of the to used teaching materials as reference is module [7], which is expected to be able to streamline communication and interaction between teachers and students in CNC learning. The research results of Wijanarka (2012) show that the development of learning module effective to shaping students competencies in accordance with the demands of the curriculum and all CNC competency standards can be achieved by students after applying and using module [8]. Based on the results of preliminary study at Vocational High Schools in Surakarta, there are some teachers who do not use the module when delivering CNC learning. Although there are, the material discussed in module is not accordance with the type of CNC machines in the Vocational High Schools.

Learning media that can be used to support CNC learning are computer software, such as Computer Aided Manufacturing (CAM), which has graphic facilities for simulating machining before being implemented on real machines to prevent errors during the CNC machining process. The research results of Abdulrasool (2010) indicate that CNC learning process with the help of computer software and CAD/CAM modules can improve effectiveness and learning outcomes when compared to manual/conventional learning [9]. With computer assisted learning, students are expected to be actively involved in learning, so teacher centered learning changes to student centered learning [10].

In addition to infrastructure, teaching materials, and media learning, the learning strategies used by teachers in teaching can also support the achievement of learning goals [11]. The research results of Yalcin (2009) show a statistical difference between the experimental group students taught by the PjBL method and the control group [12]. Some teachers of CNC learning at Vocational High Schools in Surakarta still teach using conventional learning models and teacher centered. The selection of learning strategies must be based on consideration that students as learning subjects have experience, knowledge, and desire to learn, and have confidence that they are capable and able to learn. Learning strategies are needed to integrate students theoretical and practical abilities, so that they can achieve the overall CNC Machining Technique competencies.

2. Method

The research used is Educational Research and Development (R & D), the research method used to produce or develop an educational product which is then tested for its feasibility and effectiveness [13]. This type of development research is designed using ADDIE model development research which consists of five steps, that are: (1) Analyze; (2) Design; (3) Development; (4) Implementation; and (5) Evaluation. The research on the development of the ADDIE model was chosen because it has a complete development stage, as well as instructions and development steps arranged in a sequential and systematic manner [14].

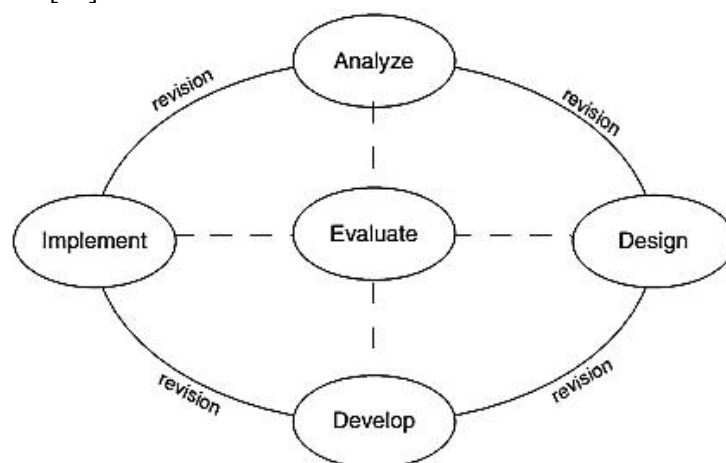


Figure 1. ADDIE Development Model [15]

Application of modules is carried out through internal trials by expert and external trials which can be said as field test. Data for external trials evaluation can be done through pretest-posttest, and if possible interview [16]. Data analysis obtained from the results development of the ADDIE model was carried out descriptively. The questionnaire was analyzed to provide an overview of the quality of the CNC learning module that was developed and the improvement of the module based on the input and suggestions given. Descriptive analysis of qualitative data was carried out on data from preliminary studies, while descriptive analysis of quantitative data was carried out through statistical calculations to analyze product trial results data.

3. Results

3.1 Results of Expert Appraisal

Module must be assessed first by experts consisting of material expert and media expert to determine whether the module is ready to be tested in the field.

3.1.1 Material Expert Assessment from the Education. The results of material expert assessment from education obtained an average score of 3.98 with good module criteria, and percentage of module feasibility showed 79.62% with module qualifications feasible to be used.

Table 2. Results of Recapitulation Material Expert Questionnaire from Education

No.	Aspect of Evaluation	Amount of Item Score	Average Score	Percentage Score	Feasibility Level
1	Feasibility of Module Contents	13	3,9	78,46 %	Feasible
2	Grammar	11	4	80 %	Feasible
3	Presentation of Module Contents	9	4	80 %	Feasible
4	Module Benefits	7	4	80 %	Feasible
Average Assessment Score			3,98	79,62 %	Feasible

3.1.2 Material Expert Assessment from Industry. The results of material expert assessment from industrial world obtained an average score of 4.34 with excellent module criteria, and percentage of module feasibility showed 86.95% with module qualifications very feasible to be used.

Table 3. Results of Recapitulation Material Expert Questionnaires from Industry

No.	Aspect of Evaluation	Amount of Item Score	Average Score	Percentage Score	Feasibility Level
1	Feasibility of Module Contents	13	4,3	86 %	Very Feasible
2	Grammar	11	4,27	85,4 %	Very Feasible
3	Presentation of Module Contents	9	4,11	82,2 %	Very Feasible
4	Module Benefits	7	4,71	94,2 %	Very Feasible
Average Assessment Score			4,34	86,95%	Very Feasible

3.1.3 Learning Media Expert Assessment. The results of learning media expert assessment obtained an average score of 4.2 with excellent module criteria, and percentage of module feasibility showed 84.04% with module qualifications very feasible to be used.

Table 4. Recapitulation of Learning Media Experts Questionnaire

No.	Aspect of Evaluation	Amount of Item Score	Average Score	Percentage Score	Feasibility Level
1	Module Size	4	4,25	85%	Very Feasible
2	Module Cover Design	11	4,27	85,55%	Very Feasible
3	Module Contents Design	25	4,08	81,6%	Very Feasible
Average Assessment Score			4,2	84,04%	Very Feasible

3.2 Field Trial Results

Field trials were conducted twice, that are small group trials and large group trials using the experimental method.

3.2.1 Small Group Trials. Small group trials were carried out in one of Vocational High Schools in Surakarta which had CNC machining facilities that were in accordance with the modules developed, that is Warga Vocational High School. Based on the results of filling in student response questionnaires obtained an average score of 4.06 with good module criteria and percentage of module feasibility show 81.2% with module qualifications feasible to be used.

Table 5. Results of Student Response on Small Group Trials

No.	Aspect of Evaluation	Amount of Item Score	Average Score	Percentage Score	Feasibility Level
1	Presentation of Material	15	4,04	80,8 %	Feasible
2	Grammar	7	4,27	85,4 %	Very Feasible
3	Display/Graphics	6	3,92	78,4 %	Feasible
4	Module Benefits	12	4,03	80,6 %	Feasible
Average Assessment Score			4,06	81,2 %	Feasible

3.2.2 Large Group Trials. Large group trials were conducted on two Vocational High Schools which were considered able to represent other Vocational High Schools in Surakarta, that are Surakarta State Vocational High School 2 and Warga Vocational High School. The application of modules in the two Vocational High Schools uses an experimental approach with aim to determine the feasibility and effectiveness of module by comparing how much learning increases between experimental class or class using modules with control classes or classes that do not use modules (10). Data from the results of large group trials show that average value of experimental class students in both the cognitive and psychomotor domains is higher than the value of the control class students.

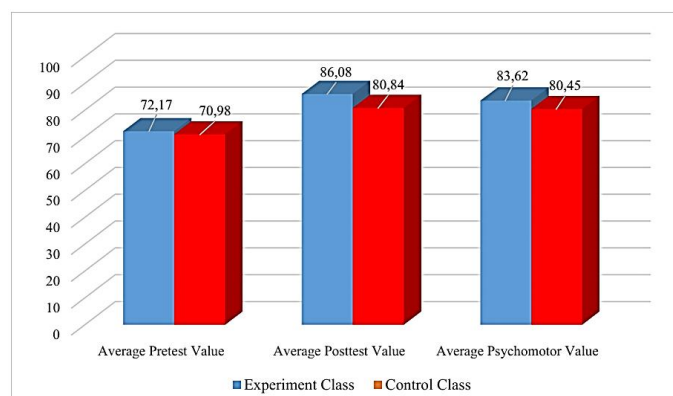


Figure 2. Comparative Diagram of Value Students of Experimental Class with Control Class at Surakarta State Vocational High School 2

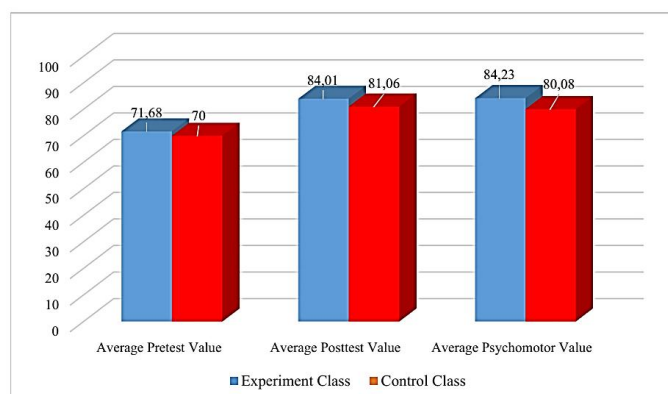


Figure 3. Comparative Diagram of Value Students of Experimental Class with Control Class at Warga Vocational High School in Surakarta

The results of questionnaire analysis at Surakarta State Vocational High School 2 students showed an average score of 4.26 with very good module criteria and percentage of module feasibility showed 85.35% with module qualifications very feasible to be used in CNC learning.

Table 6. The Questionnaire Analysis of Students in Surakarta State Vocational High School 2

No.	Aspect of Evaluation	Amount of Item Score	Average Score	Percentage Score	Feasibility Level
1	Presentation of Material	15	4,25	85%	Very Feasible
2	Grammar	7	4,29	85,8%	Very Feasible
3	Display/Graphics	6	4,30	86%	Very Feasible
4	Module Benefits	12	4,23	84,6%	Very Feasible
Average Assessment Score			4,26	85,35%	Very Feasible

The results of questionnaire analysis at Warga Vocational High School students showed an average score of 4.32 with very good module criteria, and percentage of module feasibility showed 86.4% with module qualifications very feasible to be used in CNC learning.

Table 7. The Questionnaire Analysis of Students in Warga Vocational High School

No.	Aspect of Evaluation	Amount of Item Score	Average Score	Percentage Score	Feasibility Level
1	Presentation of Material	15	4,39	87,8%	Very Feasible
2	Grammar	7	4,23	84,6%	Very Feasible
3	Display/Graphics	6	4,36	87,2%	Very Feasible
4	Module Benefits	12	4,30	86%	Very Feasible
Average Assessment Score			4,32	86,4%	Very Feasible

The results of questionnaire analysis of the responses Surakarta State Vocational High School 2 teachers obtained an average score of 4.89 with very good module criteria, and module feasibility percentage was 97.9% with module qualifications very feasible to be used in CNC learning.

Table 8. The Questionnaire Analysis of Teacher in Surakarta State Vocational High School 2

No.	Aspect of Evaluation	Amount of Item Score	Average Score	Percentage Score	Feasibility Level
1	Presentation of Material	13	4,85	97 %	Very Feasible
2	Grammar	11	4,73	94,6 %	Very Feasible
3	Display/Graphics	9	5	100 %	Very Feasible
4	Module Benefits	7	5	100 %	Very Feasible
Average Assessment Score			4,89	97,9 %	Very Feasible

The results of questionnaire analysis of the responses Warga Vocational High School teachers obtained an average score of 4.68 with very good module criteria, and module feasibility percentage was 93.7% with module qualifications very feasible to be used in CNC learning.

Table 9. The Questionnaire Analysis of Teacher in Warga Vocational High School

No.	Aspect of Evaluation	Amount of Item Score	Average Score	Percentage Score	Feasibility Level
1	Presentation of Material	13	4,46	89,23%	Very Feasible
2	Grammar	11	4,64	92,73%	Very Feasible
3	Display/Graphics	9	4,78	95,55%	Very Feasible
4	Module Benefits	7	4,86	97,14%	Very Feasible
Average Assessment Score			4,68	93,7%	Very Feasible

4. Discussion

4.1 Analyze

In analysis phase a preliminary study was conducted on Vocational High Schools in Surakarta that have a Mechanical Engineering Department conducted through literature studies, observations, and interviews which then the results are translated into several aspects, including document analysis, learning analysis, analysis of observation results, analysis of books and internet, and analysis of interview results. At this stage a general analysis of the curriculum and aspects of learning is applied to Vocational High Schools in Surakarta. The curriculum analysis carried out cover core competencies, basic competencies, competency achievement indicators, and learning materials to determine which competencies require learning modules, for example in CNC Milling competency.

In analysis phase a preliminary study was also conducted on the CNC learning process to find out the learning needs as material to develop a learning module for CNC Milling Machining Techniques. Data needed in the form of completeness of infrastructure, teacher teaching process, modules, learning media, and learning strategies used. From the results of analysis, it was found that a problem must be followed up, such as the need for a CNC learning module and used as a material consideration for designing the design Project Based Learning Module of CNC Milling Machine Techniques.

4.2 Design

The design phase is development stage which is Project Based Learning Module of CNC Milling Machining Techniques using a scientific approach in accordance with 2013 Curriculum.

4.2.1 Module Framework. The learning module of CNC Milling Machining Techniques is arranged in sequence starting from the title page, cover, preface, table of contents, module position map, glossary, introduction, learning CNC, learning activities, closing, bibliography, and attachments. In the

introductory section, the background for making the module is explained, the prerequisites students must have before using the module, instructions for using the module for both students and teachers, learning tools that support learning, the final goals to be achieved from the use of modules, core competencies and basic competencies, and checklists students initial abilities.

4.2.2 Systematics of Module Material Presentations. The systematic of module material presentation is based on core competencies and basic competencies in CNC Machining Techniques which have been translated into learning indicators. The material presentation in the module is divided into five learning activities, which in each learning activity contains learning objectives, material descriptions, and formative tests.

4.2.3 Module Assessment Instruments. The module assessment instrument consists of grids and several aspects of assessment. Module assessment is carried out by several parties, including assessment of material expert from the world of education and industry, learning media expert, CNC learning teachers, and students as respondents. Assessment of material expert from the world of education and industry includes aspects of the feasibility of module content, grammar, presentation of module content, and project based assessment. Learning media expert assessments cover aspects of module size, module cover design, and module content design. In addition, there is also an assessment from teachers which includes the feasibility aspects of the module content, grammar, presentation of the module contents, and the benefits of using the module. While assessment of students includes aspects of material presentation, grammar, appearance/graphics, and benefits of using module.

4.3 Development

Development is stage of producing product development which is carried out through internal validation and external validation. Internal validation is carried out by expert in their fields, while external validation is done by field trials consisting of small group trials and large group trials. At this stage of development several action modules were developed, including:

4.3.1 Draft Module Writing, consists of covers, introductory words, table of contents, module position map, glossary, introduction, learning activities (material, practice questions, job sheets, and evaluations), closing, bibliography, and attachments.

4.3.2 Module Editing, carried out by paying attention to module specifications, including in the form of printed media which are arranged in clear and easy to understand languages, and are based on the curriculum used in Vocational High Schools, that is 2013 Curriculum.

4.3.3 Module Validation, carried out in two stages namely internal validation and external validation. carried out in two stages that are internal validation and external validation. Whereas external validation is carried out by students and teachers after learning with modules. All of these validations were carried out to measure the feasibility level of module as learning teaching material for CNC Machining Techniques.

4.4 Implementation

The implementation for Project Based learning modules of CNC Milling Machining Techniques was carried out on XII class students of Mechanical Engineering Department at Vocational High Schools in Surakarta, namely in Surakarta State Vocational High School 2 and Warga Vocational High School. Both of these Vocational High Schools were chosen because they were considered to represent CNC learning at Vocational High Schools in Surakarta. In implementing this module learning students are trained to learn individually and in groups starting with discussions about material, looking for other learning resources, and working together in working on tasks and projects discussed in module. The

implementation phase aims to determine students understanding in using CNC learning modules, as well as to determine level of readability of module and student responses regarding the modules used.

From the implementation of the module in small groups, some suggestions and inputs must be revised to make module better. After revision, module still needs to be implemented in a larger group, namely in the broader group of students or classes in several Vocational High Schools in Surakarta. In the implementation phase of a large group, a project based learning strategy is used to find out whether the revised module is already suitable for use in CNC learning at Vocational High Schools in Surakarta.

4.5 Evaluation

Evaluation of the results of product implementation shows that module is suitable for use in CNC learning, but only requires some repairs or revisions. Improvement include revisions to content, presentation/appearance, and others. Improvements made are efforts to improve module based on the results of assessment of expert, as well as the results of assessment and interviews with teachers and students. Improvements can be in the form of adding module supporters and not substance improvements. The conclusion that can be drawn at this stage is that CNC learning module developed is suitable for use in CNC learning.

Evaluation of development and use of modules is done through a scientific approach based on the results of evaluations from validators or experts, teachers, student responses, and the results of module implementation in small groups and large groups at Vocational High Schools in Surakarta. After the researcher has revised the evaluation phase, final product produced is a CNC learning module for Vocational High Schools students in Surakarta, whose validity has been tested and said to be appropriate as a teaching material, and known the effectiveness use of module.

5. Conclusion

Characteristics of Project Based Learning module of CNC Milling Machining Techniques developed according to CNC learning at Vocational High Schools in Surakarta, that are students can learn independently and thoroughly, including descriptions and CNC learning goals, have adaptive power to development of science and technology, and easy to read and understand students. The assessment of CNC Learning module based on material expert obtained an average score of 4.16 with good criteria and percentage of module feasibility showed 83.2% with module qualifications very feasible to be tested in CNC learning, while the assessment of CNC learning modules from media expert obtained an average score of 4.2 with very good criteria and percentage of module feasibility showed 84.04% with module qualifications very feasible to be tested in CNC learning. Assessment of modules by CNC learning teachers obtained an average score of 4.78 with very good criteria and percentage of module feasibility of 95.6% which indicates that module qualifications are very suitable for use in CNC learning, while response of students in use of modules obtained an average score of 4.29 with very good criteria and percentage of module feasibility 85.8% which indicates module qualifications are very feasible to be used as learning materials for CNC learning at Vocational High Schools in Surakarta. The research and development results show that Project Based Learning module of CNC Milling Machining Techniques is very helpful for students in improving their learning outcomes as evidenced increase student grades by 17.09%, and helping students completely CNC Machining Techniques as evidenced by 100% of students gaining value $\geq$ minimal completeness criteria.

6. References

- [1] Kemendikbud. (2013). *Permendikbud RI Nomor 70, Tahun 2013, tentang Kerangka Dasar dan Struktur Kurikulum Sekolah Menengah Kejuruan*.
- [2] Republik Indonesia. (2003). *Undang-Undang RI Nomor 20 Tahun 2003 tentang Sistem Pendidikan Nasional*.
- [3] Kemendiknas. (2006). *Permendiknas RI Nomor 23, Tahun 2006, tentang Standar Kompetensi Lulusan untuk Satuan Pendidikan Dasar dan Menengah*.
- [4] Kemendiknas. (2009). *Permendiknas RI Nomor 28, Tahun 2008, tentang Standar Proses Pendidikan Dasar dan Menengah*.
- [5] Ditpsmk. (2017). *LKS CNC Milling Kota Surakarta*. Diakses pada tanggal 13 September 2015, dari: <http://event.ditpsmk.net/lks2017/cnc-milling>
- [6] Arends, R.L. (2004). *Exploring teaching an introduction to education*. New York & London: Routledge Falmer.
- [7] Komalasari, (2010). *Media pengembangan pembelajaran*. Jakarta: PT. Gramedia.
- [8] Wijanarka, B.S. (2012). *Pengembangan modul dan pembelajaran kompetensi kejuruan teknik pemesinan CNC SMK*. Disertasi, Universitas Negeri Yogyakarta, Yogyakarta.
- [9] Abdulrasool. (2010). *The Effect of Using Computer Technology Tools to Enhance the Teaching-Learning Process in CAD/CAM-CNC Module in Mechanical Engineering*. Journal of Information and Education Technology. Association for the Advancement of Computing in Education (AACE), ISBN 1-880094-79-7.
- [10] Sanjaya, W. (2009). *Strategi pembelajaran berorientasi standar proses pendidikan*. Jakarta: Kencana.
- [11] Joice, B. & Weil, M. (2004) *Models of teaching (7th ed.)*. Boston: Pearson education.
- [12] Yalcin, S.A., Turgut, U. & Buyukkasap, E. (2009). *The Effect of Project Based Learning on Science Undergraduates Learning of Electricity, Attitude Physics and Scientific Process Skills*. Ataturk University, International Online Journal of Educational Sciences. No.1, pp. 81-105.
- [13] Sugiyono. (2013). *Metode Penelitian Pendidikan: Pendekatan Kuantitatif, Kualitatif, dan R & D*. Bandung: Alfabeta.
- [14] Pribadi, B.A. (2009). *Pengembangan sistem pembelajaran*. Bandung: Pelita Ilmu.
- [15] Branch, R.M. (2009). *Intructional design: The ADDIE approach*. University of Georgia.
- [16] Dick, W. & Carey, J.O. (2005). *The systematic design of instruction (6th ed.)*. Boston: Pearson Education Inc.