Prototype of Physic Lessons Based on Microcontroller to Increase Students' Conceptual Understanding

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Abstract: ***One of the efforts to increase students' conceptual understanding in physics lessons is to utilize various learning media as tools of learning aid. This research aims to develop prototype of lessons that are accurate, valid, effective and practical as learning media in order to optimize conceptual understanding regarding rotational movement of rigid object. The prototype of physics lessons that have been developed are props based on microcontroller, lesson modules, Students Exercise, Practical Guides, Lesson Plan, and various tests. The prototype itself has been cultivated using Research and Development Method through the ADDIE approach. Test of Effectiveness of the prototype was conducted through a pre-experimental design – one group pretest-posttest which involved students of the physics department of STKIP SoE. Data gathering was completed through validation paper, observation, tests and surveys. Results of validation tests through expert tests shows that the prototype has been developed in highly valid category. Research results show that the prototype positively influences students' conceptual understanding. Trial for effectiveness through the N-gain test shows an increase in conceptual understanding in low category. Whereas practical test shows that the developed prototype lessons are very practical to utilize as a learning media.***

Keywords: props, prototype, microcontroller.

1. Introduction

Physics is a physical science that studies all sorts of symptoms and natural phenomenon using various scientific methods within the sphere of space and time. Physics is a field that is studied at all stages of education, from primary to tertiary level. This is because physics has a vital role in the advancement of science and technology in the efforts of constructing a cultured and modern life. However, amongst students at present days, physics has become a challenging field to study due the great amount of concepts and formula within it. The main source of challenge in learning physics is that the learning methods are still too conventional with an emphasis to prove of concept and the lack of supporting tools including props.

Efforts to transforms physics into a field that is enjoyable and more easily understood may include providing learning aids. Such learning aids may serve as media to connect between educator and students during learning process so that the analysis of theory and physic related concepts becomes less challenging tasks. This is because the use of props during lessons encourages emergence of new interests and motivations, stimulates learning and even impacts the students psychologically. Such props may become tools of aid to better convey a message, so that it is less verbal, solves the limitation of space, and shares the same experience and perception to students [1]. Moreover, Dale's Cone of Experiment in Susilana, et al., (2007) acknowledges that the experience of learning through actively doing, will explain a concept in real time and students will remember 90% of what they have done [2]. Therefore, lessons are easier to memorize when they are conveyed through the correct media.

Advancement of science and technology allows the creation and improvement of various sensors and control device which we can utilize to design various props. One of the electronic control devices that haves been widely used in the development of physics props and learning tools is microcontroller. Microcontroller is an appropriate apparatus to overcome numerous deficiencies of other manual and conventional props. A lot of features in microcontroller may be employed to conduct automatic measuring which results in higher accuracy. Learning tools that have utilized microcontroller includes the measuring of earth gravity acceleration through the use of pendulum [3], structural design of fluid viscometer with the free-falling ball method [4], innovation in learning of science and technology in Junior High School based on the use of microcontroller [5], and the design of practical learning module of basic physics to measure viscosity [6]. Of all learning tools that have been designed and implemented in actual learning, it has been found that there was an increase of understanding of physics concepts and a rise of interest amongst students to learn physics.

2. Literature Review

Physics lessons aims to equip students with knowledge, understanding, skills and ability to further develop science and technology. However, during learning process students face abstract concepts that are not part of everyday life, which results in difficulty to understand lessons presented by teachers. Visualization is an employable method and medium to give body to abstract concept. According to Daryanto (2013), learning process is essentially a communicative process which needs certain media to increase the quality of learning results [1]. Ibrahim and Syaodih (2003) defines learning media as all tangible things that are able to convey message or lessons and stimulates students to learn more [7].

Learning media have vital roles in learning process, because it can raise the level of interaction between teachers and students so it may proceed optimally. According to Daryanto (2013), learning media serves to clarify certain message, preventing it from becoming overly reliant on verbal communication, overcome limitations of space, time, energy and sensory abilities; stimulates learning vigor, allows students to study independently in accordance with their natural tendencies such as through visual, audio and kinesthetic, as well as offers the same stimuli and perception [1]. One of the learning media that is employable in learning process is props, because props is an effective tool communicate and convey abstract concept, and encourage interest among students. It has been expressed by Sudjana (2011) that props are learning media that contains and possesses qualities of concepts to be studied [8].

Props are communication device and tools that facilitates interaction between teachers and students during learning process [9]. According to Iswaji (2003), props are a set of tangible objects that have been designed, created or organized deliberately to aid to instill or develop concepts or principles in learning [10]. Props are utilized as a media to convey message to stimulate the mind, emotions, attention and interest among students in learning. The use of props allows students to gain knowledge and develop psychomotoric abilities, as well as encourages students' creativity to solve challenges. Thus, it creates high quality learning process [8].

Props are learning media with essential role in learning process of physics lessons. The use of props in learning activities overcomes abstractness of physic concepts that are normally quite challenging to grasp, it also aids in scientific work flow and improves general attitudes of students [11]. Props may be used as effective media to boost quality of learning process [12], increase conceptual understanding of physics [13], develop critical thinking ability [14], better academic achievements [15], increase interest in learning [16], as well as improve innovativeness and creativity of learners [17].

Understanding is a lower-level cognitive ability that is at a higher level than knowledge. The ability possessed at this level is the ability to obtain meaning from what has been learned. Bloom differentiates understanding into three categories: at the lowest level is the understanding of translation and at the highest level is comprehension of extrapolation. Conceptual understanding drives learners to independently improve their knowledge of what has been learned so as to boost cognitive ability in learning. To measure the level of conceptual understanding of learners, one can utilize seven indicators: *interpreting*, *comparing*, *classifying*, *inferring*, *exemplifying*, *summarizing*, and *explaining* [8]. In the process of learning physics, there is a need for abilities to understand abstract concepts. Visual aids are a very effective medium and necessary to enhance the conceptual understanding of abstract conceptions in physics. Many studies have been undertaken to develop physics learning aids that can be utilized during learning process to enhance conceptual understanding, such as DC-Series Parallel for Ohm's Law [18], Archimedes' pulley props [19], as well as hydraulic pump props as well as Boyle's balloon [20].

Microcontroller as a controller device that is flexible and practical because it is not too complex and requires high computational load. Microcontroller is able to automate and control a system independently (standalone) [21]. Microcontrollers have been widely used as input and output control devices to embody physical props. The props developed using microcontrollers are automatic, digital, and have a higher accuracy of measurement results compared to conventional props. Some microcontroller based physics props have been developed as learning media, such as viscometer [22], DC ammeter [23], strain gauge [24], conductivity measuring instrument [25], teslameter [26], fluid velocity measuring devices [27], and optical power measuring devices [28].

3. Research Methods

This research uses Research and Development (R & D) method which refers to the development model of ADDIE (Analyze, Design, Develop, Implement, and Evaluate) to develop prototype of physics learning on rotational material of rigid body [29]. Whereas testing the effectiveness and practicality of prototype was conducted using pre-experimental method with one group pretest-posttest design. The prototypes of physics learning developed in this study are: (1) rotational auxiliary instrument tool on microcontroller-based incline, (2) teaching module, (3) Student Worksheet (4) laboratory guide, (5) Lesson Plans, and (6) learning evaluation questions in improving students' conceptual understanding.

This research involves students of Physics Department of Sekolah Tinggi Ilmu Keguruan dan Pendidikan SoE (STKIP SoE), in East Nusa Tenggara Province, Indonesia. The test instruments used in this research are: (1) observation sheet, (2) validation sheet, (3) concept comprehension test questions, and (4) student response questionnaire. Steps of development with the ADDIE approach in this study are:

1) *Analyze* is an analytical stage regarding the need for product to be developed. At this stage, there is an analysis concerning the need for instructional media in the Physics Department in STKIP SoE through observation. This observation aims to collect data regarding specific learning media that are needed for basic physics lessons.
2) *Design* is the planning stage of prototype development of physics learning. At this stage, prototype models of props, teaching modules, MFIs, practical guides, lesson plans, and test questions are developed through the identification and collection of data to fit the needs and available resources.

3) *Develop* is the design stage of prototype of physics learning. At this stage, we design a prop for rigid body rotational tool on an incline based on microcontroller. The design of the visual aids is complemented by the development of interactive teaching aids with teaching aids, MFIs and practical guides for props developed, lesson plans and test questions in line with learning objectives. At this stage, an evaluation instrument for effectiveness and practicality testing and validation sheet was developed to validate the prototype.
4) *Implement* is a trial phase to gauge the precision, accuracy, validity, effectiveness and practicality of the developed prototype. The produced prop is then tested for precision and accuracy by investigating the constant inertia of a solid sphere. Validity of the prototype is obtained through specific tests, both media test as well as material tests. Whereas tests of effectiveness and practicality that were developed were checked by using experimental method: *pre-experimental* with one group *pretest-posttest* as shown in in table 1. Sedangkan keefektivan dan kepraktisan prototipe pembelajaran fisika yang dikembangkan diuji melalui metode *pre-experimental* dengan desain *one group pretest-posttest* seperti ditunjukkan pada Tabel 1. This trial finds out the effectiveness of the developed prototype in enhancing conceptual understanding and practicality of the prototype as physics learning media.

Table 1: Research design for prototype testing

Pretest	*Treatment*	*Posttest*
O_1	X	O_2

Modified from [30]
Keterangan:
O_1 = *pretest* score of conceptual understanding
O_2 = *posttest* score of conceptual understanding
X = Treatment by application of prototype of physics learning

5) *Evaluate* is revision phase of the prototype and evaluation of student learning process using prototype of physics learning that has been developed. At this stage, a process of improvement is done based on analysis of test results at the implementation stage. pembelajaran mahasiswa menggunakan prototipe pembelajaran fisika yang dikembangkan. Pada tahap ini, dilakukan proses perbaikan berdasarkan analisis hasil ujicoba pada tahap implementasi.

Data analysis technique utilized in this research is a calculation with the Likert Scale, t-test and N-gain test. Calculation with Likert Scale is employed to analyze the validity and practicality of the prototype. Percentage of validity and practicality of the prototype is determined with the following interpretation: (1) "Totally Invalid/Impractical" with score percentage of 0% - 25%, (2) "Invalid/Impractical" with percentage score of $26\% - 50\%$, (3) "Valid/Practical" with percentage score of $51\% - 75\%$, and (4) "Highly Valid/Practical" with percentage score of $76\% - 100\%$. The *t-test* and *N-gain* tests were then applied to analyze the effectiveness of the prototype. The *t-test* is a statistical test to determine the difference in levels of conceptual understanding before and after the application of the prototype of the physics learning that has been developed in the actual learning process. The *N-gain* test was utilized to measure the increase in conceptual understanding. According to Hake in Meltzer (2002), the score of *N-gain* can be classified as follow: (1) If *N-gain* is > 70% then it falls within the high range; (2) if 30% ≤ N-*gain* ≤ 70%, then the *N-gain* is in medium range; (3) if *N-gain is* < 30%, then it falls on low range [31].

4. Results and Discussion

During the introductory course, it has been discovered that students in general are having difficulties in understanding the concepts of rotational movements of solid object and the misconception in the case of rolling object. Learners are still under the impression that solid object such as a solid sphere, solid cylinder and thin, hollow cylinder that roll on sloping surfaces will arrive at the base simultaneously. Such misconception emerges due to the lack of innovative interactive media to make it easier for learners to comprehend the phenomenon of rotational movements of solid object. Learners will possess and construct their own concept correctly if they are given the opportunity to independently experience what they learn through the correct learning media.

According to Anonymous in Presetyarini, et al., (2013), a high quality learning process will emerge when learners are given opportunity to learn actively in order to enable them to obtain knowledge and develop psychomotoric ability as well as encourage creativity to solve problems they are facing [13]. Implementation of physics learning prototypes such as the use of visual or instructional aids, interactive learning modules, students worksheet and practical guides during learning process can reduce the level of learners' difficulties in understanding abstract concepts and assist teachers in during lesson delivery, so that the conveyance of such concepts are more meaningful, and thus enhance learner's understanding concerning the concepts being studied. When explaining abstract notions, learning media are very useful to show and prove the concepts themselves or the symptoms.

The development of physics learning prototype results in a prop based on microcontroller as shown in Figure 1. The design of this prop consists of two parts: hardware design and software design. The hardware comprises of a series of microcontrollers, infrared sensor, LCD, pushbutton, actuator, a power supply unit and mechanical system prop. The software utilizes C++ programming language. The microcontroller acts as the main controller of the prop to regulate the performance of electrical components and measure time using the internal microcontroller timer. The infrared sensor serves as a detector to detect the movement of the sphere, the LCD then shows the time measurement results, pushbutton is a tool for input of command to the microcontroller, actuator as the circuit to control magnetic field on the metal bar, and power supply serves to provide power to the electronic components of the props.

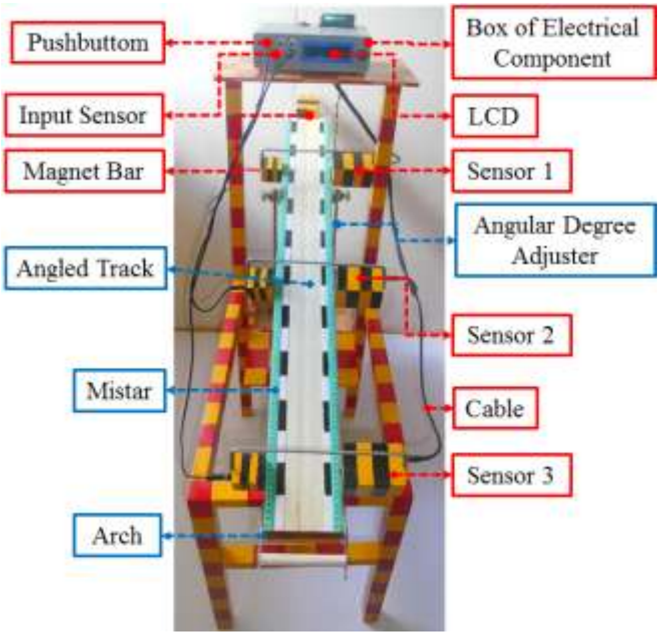

Figure 1: Design of props/learning aid

This prop also supported with learning module, student worksheet, practical guide and lesson plan. These products discuss topics regarding rotational movements and their translation, rotational motion's constant acceleration, relationships among rotational variables and their translations, kinetic rotational energy, moment of inertia, force moment, rolling motion, angular momentum, and energy conservation mechanical law. These products have also been validated and the validation results as shown in Table 2. This validation is an internal validation done by the experts via media test and expert test. The validation results shows that the average percentage of product is 91.25% (highly valid) which means they are appropriate to use as tools of aid during learning process.

Application of learning prototype that has been developed was conducted on a sample of 32 students of the physics department. This trial was analyzed using the *one sample t-test.* The test aims to discover the influence of learning aid utilization to the conceptual understanding of learners. The *t-test* was conducted after the fulfillment of requirements, that is, the normal distribution of data used in the test. The test results obtains a score of $t_{calculation} > t_{table}$ at the significance level of 5%. Based on this result, thus H_o is declined and H_a is accepted, which means that there is an increase in level of conceptual understanding due to the use of physics learning prototype during lessons.

The increase in conceptual understanding can be analyzed in *pretest* and *posttest* results. The outcome of conceptual understanding tests during *pretest* and *posttest* shows noticeable difference between the lowest score, highest score and average score as shown in Figure 2. The graphic in Figure 2 shows that there is an increase in all those scores after the use of physics learning prototype during lessons. The change of score obtained by learners is quite significant. This result is influenced by the minimal initial knowledge of learners, which means that the use of physics learning prototype proves useful in enhancing their conceptual understanding, especially regarding indicators that interpret, infer, summarize and explain. There is also a significant increase of highest and average scores. The rise occurs because students are able construct new knowledge and improve misconceptions about the concept of rotational motion of rigid bodies and rolling motion. It is possible for the cognitive aspect of conceptual understanding to improve because learners are given the opportunity to experience and explore their own knowledge through experiments using the developed prototype. This opinion is in line with the results of research conducted by Erintina (2015) that the application of props in the learning process can improve cognitive learning outcomes and give a boost to the enthusiasm and interests of learners [17]. The same research results were also obtained Prasetyarini, et al., (2013) that the application of props in the learning process can improve conceptual understanding among learners [13].

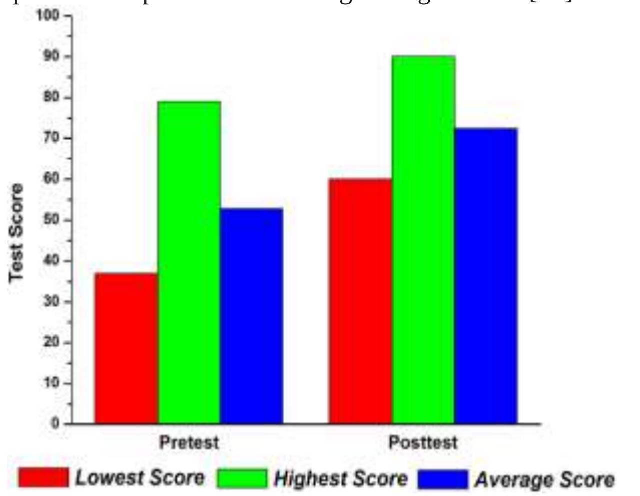

Figure 2: Result of conceptual understanding test on implementation phase

When categorized in low, medium, and high, the percentage of pretest and posttest results show improvement in conceptual understanding after learning process using visual aids as shown in Figure 3. The percentage of understanding of the concept of low category decreases. These results indicate that after being taught by using the physics learning aid (props), there is certain decrease (in percentage) of ignorance and misconception in students without prior knowledge regarding the concept of rotational movements of rigid bodies and rolling motion. This reduction is a positive influence of the application of props because students are able to construct their own understanding. In addition, the existing conceptual abstraction is not an obstacle to understanding physics phenomena especially for students with preference to visual learning. According Daryanto (2013) learning styles affect learners in receiving and storing information concerning lessons, which means that appropriate media is needed to allow learners study easily and quickly understand lessons [1].

On Figure 3, it is observable that there is also an increase in the level of conceptual understanding in the medium category. The escalation takes place because the use of learning aid/props assists learners to better understand and expand their knowledge about rotational motion of solid objects and rolling motion on an angled surface. The props used during lessons become an effective media to enhance conceptual understanding and learning achievements. An investigation by Muhaimin, et al., (2015) shows that the utilization of learning aid in lessons improves learners' conceptual understanding as well as their attitude towards science [32]. Similar results are also shown by Sumbadi & Mosik (2009) who discover that utilization of props during lessons facilitates a rise in cognitive learning achievement of students [33]. The effectiveness of physics learning prototype for rotational motion of solid object and rolling motion to enhance conceptual understanding is also assessable by means of N-gain test. Results of N-gain test analysis from each conceptual understanding indicator are shown in Table 3. It is observable in the N-gain test result that there are certain escalations on indicators for comparing, summarizing and explaining in the low category; whereas on indicators for interpreting, giving examples, and inferring, the increase occurs in the medium category. The average score of N-gain however, falls on the lower category at 27.61%. These results clearly indicate that there is an increase in the conceptual understanding due to the use of physics learning prototype in the learning process.

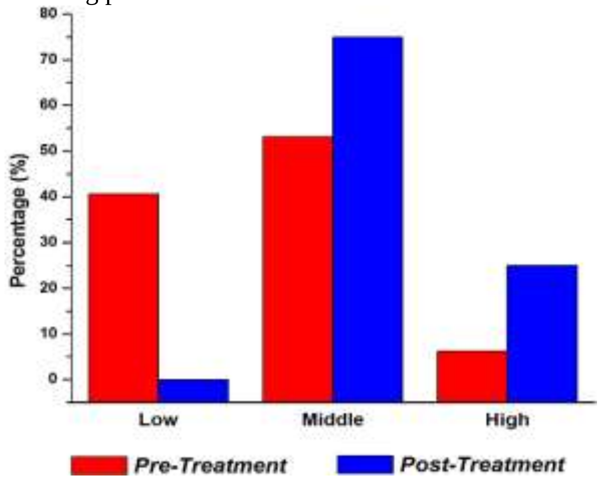

Figure 3: Results of conceptual understanding test before and after the treatment (in percentage)

Table 2: Result of prototype validation

Product/ Prototype	Validator			Average	Percentage (%)
	1	2	3		
Learning Aid/Props	3.8	3.7	3.8	3.8	94.4
Learning Module	3.7	3.4	3.6	3.5	88.4
Practical Guide	3.8	3.6	3.6	3.6	90.1
Student Worksheet	3.7	3.5	3.4	3.5	89.4
Lesson Plan	3.8	3.6	3.8	3.7	91.9
Test questions	3.7	3.7	3.8	3.8	94.0
Average				3.65	91.25

Table 3: Generalisation of score <g> learners' conceptual understanding

Indicator	Before (O_1)	After (O_2)	<g> (%)	Categori
Interpreting	23.13	48.13	32.52	Medium
Comparing	28.13	34.38	8.70	Low
Giving examples	23.44	54.69	40.82	Medium
Making Inference	33.75	58.13	36.79	Medium
Summarizing	16.67	36.46	23.75	Low
Explaining	32.03	47.66	22.99	Low
Average	46.57	26.19	27.61	Low

Students' response to the physics learning aid prototypes that have been developed such props, learning module, student worksheet, practical guide, lesson plan and test questions has been acquired through a survey given at the end of the lesson. The survey itself consists of four elements: response concerning the use of prototypes, deliverance of lessons using the prototype to understanding concepts, incorporation of learning modules, student worksheet and practical guides, and lastly, enthusiasm towards the use of learning modules, student worksheet and practical guides. Results of response analysis are shown in Table 4. Based on the analysis of average response of learners concerning practicality of the products, it is conclusive that the said products are highly practical to use in learning process to enhance conceptual understanding.

The analysis of survey results on learners' response towards the use of learning prototypes shows that learners become more interested and motivated to construct their own conceptual understanding about rotational motion of solid object through repeated observation and measuring of experiments using the prototype. High level of students' interest and motivation can create a high quality learning process as well, which will result in better academic achievements. Such learning process facilitates learners to develop correct comprehension and the ability to memorize lessons. Dale in Susilana, Rudi & Riyana (2007) stated that learning by doing explains concepts in a real way and learners can commit to memory 90% of lessons they learn [2]. Similarly, a research by Indah and Prabowo (2014) also supports the fact that utilization of props and learning aids greatly motivates learners, resulting in more enthusiastic attitudes in conducting experiments and increased interaction and discussion in study groups [34]. Such situations make it easier for students to understand concepts within the lesson which will lead to better academic performance and achievement in general.

Table 4: Percentage of students' response to the practicality of products

Aspects of Students' Response	Percentage (%)	Categori
Students' Response to Props based on Microcontroller	85.9	Highly Positive
Lessons using props	86.6	Highly Positive
Students' Response to Learning Modules, Students Worksheet and Practical Guide	85.9	Highly Positive
Lessons using Learning Modules, Students Worksheet and Practical Guide	82.7	Highly Positive
Students' Response to the use of props and practical guide/module in an efforts to develop processing skills and scientific attitude	86.0	Highly Positive
Language model in practical guide/module, learning module, and student worksheet	83.9	Highly Positive
Average	85.2	Highly Positive

5. Summary

The prototype of physics learning aid that has been developed is valid as a learning media to enhance conceptual understanding as much as 92,4 %. The prototype is also very effective to use in lessons because it increases students' conceptual understanding of the lesson concerning rotational motion of solid object on angled surface. The increase of students' conceptual understanding associated with the use of learning aids falls into the low category at 27,61% in N-gain significance test. In term of practicality as a learning media, it has been proven that the prototype is very practical to use during deliverance of lessons, achieving a score of 85,2% in the practicality survey.

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References

[1] Daryanto, Media Pembelajaran (2nd ed.), Gava Media Yogyakarta, 2013.
[2] Susilana, Rudi, & C. Riyana, Media Pembelajaran, Wacana Prima, Bandung, 2007.
[3] Syahrul, J. Adler, Adriana, "Pengukur Percepatan Gravitasi Menggunakan Gerak Harmonik Sederhana Metode Bandul," Jurnal Teknik Komputer Unikom (Komputika), 2(2), pp. 5-9, 2013.
[4] D. Aryanto, E. Saptaningrum, Wijayanto, "Rancang Bangun Viskosimeter Fluida Metode Bola Jatuh Bebas Berbasis Mikrokontroler ATMega16," Jurnal Fisika dan Aplikasinya, 8(2), pp. 1-5, 2012.
[5] U. Rochayati, S. Waluyanti, D. Santoso, "Inovasi Media Pembelajaran Sains Teknologi di SMP Berbasis Mikrokontroler," Jurnal Kependidikan, 42(1), pp. 89-98, 2012.
[6] S. Jumianto, A. Mujadin, D. Elfidasari, "Rancang Bangun Alat Ukur Viskositas Dalam Rangka Pengembangan Modul Praktikum Fisika Dasar," Jurnal Al-Azhar Indonesia Seri Sains dan Teknologi, 2(1), pp. 48-51, 2013.
[7] Ibrahim, Syaodih, Perencanaan Pengajaran, Pusat Perbukuan Dipdikbud dan Rineka Cipta, Jakarta, 2003.
[8] N. Sudjana, Dasar-Dasar Proses Belajar Mengajar (2nd ed.), Sinar Baru Algensindo, Bandung, 2011.
[9] R. Arsyad, Media Pembelajaran, PT Rajagrafindo Persada, Jakarta, 2009.
[10] D. Iswaji, Pengembangan Media Pembelajaran Matematika di SLTP, FMIPA UNY, Yogyakarya, 2003.
[11] M. Y. Kholifudin, "Pembelajaran Fisika Berbasis Proyek Pembuatan Alat Resonansi Bunyi dari Lampu Neon Bekas Untuk Membentuk Kerja Ilmiah dan Sikap Ilmiah Pada Siswa," Pertemuan Ilmiah XXVII HFI Jateng & DIY, Solo, Indonesia, 2013.
[12] A. Isnanto, A. Maftukhin, E. S. Kurniawan, "Pengaruh Penggunaan Alat Peraga Berbasis Lingkungan (APBL) Pada Materi Dinamika Partikel Terhadap Kemampuan Psikomotorik P1 Peserta Didik Kelas X SMA Negeri 1 Kutowinangun," Radiasi, 4(1), pp. 30-33, 2014.
[13] A. Prasetyarini, S. D. Fatmaryanti, R. W. Akhdinirwanto, "Pemanfaatan Alat Peraga IPA Untuk Meningkatkan Pemahaman Konsep Fisika Pada Siswa SMP Negeri I Bulupesantren Kebumen Tahun Pelajaran 2012/2013," Radiasi, 2(1), pp. 7-10, 2013.
[14] B. Hartati, "Pengembangan Alat Peraga Gaya Gesek Untuk Meningkatkan Ketrampilan Berpikir Kritis Siswa SMA," Jurnal Pendidikan Fisika Indonesia, 6(2), pp. 128-132, 2010.
[15] N. Kusdwiutomo, "Pengaruh Pembelajaran Fisika Dengan Media Power Point Disertai Animasi dan Modul Dilengkapi Alat Peraga Terhadap Prestasi Belajar Fisika Ditinjau Dari Kreativitas Siswa," (Unpublished Tesis). Program Pasca Sarjana Universitas Sebelas Maret, Surakarta, 2008.
[16] A. Aththibby, D. Alarifin, "Pengaruh Permainan Dalam Pembelajaran Fisika Terhadap Motivasi Belajar Peserta Didik," JRKPF UAD, 2(2), pp. 38-41, 2015.
[17] M. D. Erintina, "Pengaruh Model Pembelajaran Expository Berbantuan Alat Peraga Terhadap Hasil Belajar Fisika Siswa Kelas VIII SMPN 21 Mataram Tahun Pelajaran 2014/2015," Ganec Swara, 9(1), pp. 140-144, 2015.
[18] G. A. Riyanti, Sutikno, Masturi, "Perenapan Alat Peraga Seri-Paralel DC Untuk Meningkatkan Pemahaman Siswa Pada Materi Hukum Ohm," Prosiding Seminar Nasional Fisika (E-Journal), Jakarta, Program Studi Pendidikan Fisika dan Fisika, Fakultas MIPA, Universitas Negeri Jakarta, 2015.
[19] I. A. Palupi, "Upaya Peningkatan Pemahaman Konsep Hukum Archimedes Melalui Alat Peraga 'Katrol Archimedes' di Kelas XI IPA SMAN 3 Salatiga," Prosiding Seminar Nasional Pendidikan Sains, Salatiga, UKSW, 2015.
[20] L. Puspitarini, "Pengembangan Alat Peraga Sains Pompa Hidrolik dan Boyle's Balloon Untuk Meningkatkan Pemahaman Konsep Siswa SMAN I Sayung," (Unpublised Skripsi), Jurusan Fisika Fakultas MIPA Universitas Semarang, 2015.
[21] A. Bejo, Rahasia Kemudahan Bahasa C Dalam Mikrokontroler ATMega8535, Graha Illmu Yogyakarta, 2008.
[22] D. Ramadhan, V. Serevina, Raihanati, "Perancangan Alat Praktikum Viskometer Metode Bola Jatuh Bebas Berbasis Sensor Efek Hall UGN3503 Sebagai Media Pembelajaran Fisika," Prosiding Seminar Nasional Fisika, Jakarta, Program Studi Pendidikan Fisika dan Fisika, Fakultas MIPA, Universitas Negeri Jakarta, 2016.
[23] D. C. Wulandari, Wildian, "Rancang Bangun Ammeter DC Tipe Non-Destructive Berbasis Mikrokontroler ATMega8535 Dengan Sensor Efek Hall ACS712," Jurnal Fisika Unand, 3(2), pp. 121-127, 2014.
[24] H. Saputra, M. Yusfi, "Rancang Bangun Alat Ukur Regangan Menggunakan Sensor Strain Gauge Berbasis Mikrokontroler ATMega8535 Dengan Tampilan LCD," Jurnal Fisika Unand, 3(2), pp. 162-169, 2013.
[25] R. Syaefullah, G. Yuliyanto, Suryono, "Rancang Bangun Alat Konduktivitas Panas Bahan Dengan Metode Needle Probe Berbasis Mikrokontroler AT89S52," Jurnal Berkala Fisika, 9(1), pp. 37-42, 2006.

[26] P. Premono, N. Soedjarwanto, S. Alam, "Rancang Bangun Alat Instrumentasi Pengukuran Digital Kuat Medan Magnetik Dengan Menggunakan Mikrokontroler ATMega8535," Jurnal Rekayasa dan Teknologi Elektro (ELECTRICIAN), 9(3), pp. 160-170, 2015.
[27] M. A. Novianta, "Alat Ukur Kecepatan Fluida Dengan Efek Doppler Menggunakan Mikrokontroler AT89S51," Jurnal Teknologi, 3(1), pp. 1-9, 2010.
[28] R. Sianipar, A. Hambali, Sarwoko. "Perancangan dan Implementasi Alat Ukur Daya Optik Berbasis Mikrokontroler AVR ATMega8535 Dengan Tampilan di Komputer," (unpublished Tugas Akhir), Teknik Telekomunikasi, Fakultas Teknik Elektro, Universitas Telkom, 2012.
[29] Branch, R. Maribe, Instructional Design: The ADDIE Approaach, Springer, New York, 2009.
[30] Sugiyono, Metode Penelitian Kuantitatif, Kualitatif, dan R & D, Alfabeta, Bandung, 2011.
[31] E. D. Meltzer, "The Relationship Between Mathematics Preparation and Conceptual Learning Gains in Physics," American Journal of Physics, 70(7), 2002.
[32] A. Muhainin, Susilawati, H. Soeprianto, "Pengembangan Media Kapasitor dan Pengaruhnya Terhadap Pemahaman Konsep dan Sikap Ilmiah Siswa," Jurnal Pendidikan Fisika Indonesia, 11(1), pp. 59-72, 2015.
[33] A. Sumbadi, Mosik, "Penggunaan Alat Peraga Papan Optik Untuk Meningkatkan Hasil Belajar Pemantulan Cahaya Pada Siswa Kelas VIII," Jurnal Pendidikan Fisika Indonesia, 5(2), pp. 31-36, 2009.
[34] D. S. Indah, Prabowo, "Pengembangan Alat Peraga Sederhana Gerak Parabola Untuk Memotivasi Siswa Pada Pembelajaran Fisika Pokok Bahasan Gerak Parabola," Jurnal Inovasi Pendidikan Fisika, 3(2), pp. 89-94, 2014.

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