Improvement of engineering student's learning outcomes in high schools using adaptive educational hypermedia system

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ABSTRACT

This was a research and development (R&D) which aims to develop adaptive educational hypermedia system (AEHS) learning media. The use of AEHS based on learning style in supporting the online learning process is considered very effective for use by engineering students because it can be accessed via mobile devices which can make it easier for students to learn and has an effect on increasing learning outcomes, this is supported by several inputs from experts through expert learning design tests, learning instrument experts, learning media experts and learning outcome measurement experts with the assessment results included in the very good category. The participants in this study were informatics engineering students, totaling 100 students. Small group tests were conducted for participants and obtained a gain score of 0.735 included in the 'high' category. The pretest and posttest have been carried out and the results show that the average posttest score is greater than the pretest value. A comparison between the use of AEHS developed with web-based learning was carried out and it can be concluded that the use of AEHS based on learning styles further improves student learning outcomes in informatics engineering compared to web-based learning.

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1. INTRODUCTION

Online learning-based technological innovations are increasingly popular in the world of education. The advantage of the current online learning system is that it easily accessible anywhere and anytime. Currently there are many online learning systems on various websites, generally providing the same material for all students without considering individual differences [1]. Many studies have looked at the use of online learning in the learning process [2]. Most learning processes with online learning deliver material that is suitable for homogeneous students, when content is delivered to students with more diverse populations, it will reduce the level of efficiency because these students have different learning goals, backgrounds, levels of knowledge, learning styles, thinking styles and competence. Therefore, the process of delivering flexible learning content is needed to be designed in such a way that students who have different backgrounds and levels of knowledge will obtain learning material in different ways of presenting it.

This research will shift to adaptive learning [3], which is a research domain in education and sustainable development. Adaptive educational hypermedia system (AEHS) meets the needs of each individual user, adjusting to learning objectives or tasks, learner's level of knowledge, work context, and interests [4]. AEHS is an adaptive system application area that aims to adapt educational content and learning paths in online learning environments to minimize learner disorientation and cognitive overload problems and to maximize learning and efficiency.

In general, adaptive educational hypermedia, a user model is created based on user characteristics and adaptations are made in terms of text, content or presentation according to the created user model [5]. The modeling process is the most important part of adaptive system development [6]. Even if the model developed is correct, the content to be used in practice must be well structured and contain different presentation formats to direct users to the correct and effective content in the learning process. In other words, the domain model contains learning and the involvement of different presentation styles in the domain model are important in providing learning opportunities in independent learning [7]. In the case of AEHS, content and learning paths are tailored to the user, thereby reducing cognitive overload and disorientation to enhance learning [8], [9]. Another challenge is to design a system with the required functionality and usability that will take into account the different pedagogical teaching approaches and learning theories of different users. Although AEHS provides the necessary personalization for learners, its development is quite challenging due to the inherent complexity of the design process, which tries to harmonize educator knowledge in secondary schools and tertiary institutions [10]. Based on the explanation, this research initiated a new idea to develop an AEHS based on learning styles.

In using e-learning based learning models, the learning style and knowledge level of the learner must be considered. Learning style is a consistent style that is carried out by someone in capturing stimulus or information and how to remember to think and solve problems [11]–[13]. Learning style is a way that is preferred by students in a learning process. With a learning style, students will more easily understand lessons, which will have an impact on student performance [14], [15]. Some students prefer their educators to teach by writing lessons on the blackboard and then understanding them. However, some other students prefer teachers to teach by conveying it orally and they listen to it to be able to understand it. Meanwhile there are also those who prefer to form small groups to discuss questions related to the lesson. A person's ability to understand and absorb lessons is definitely different levels. Some are fast, medium, and some are very slow. Therefore, students often have to take different ways to be able to understand the same information or lesson. Based on this, it can be concluded that learning style is a fun way of learning and is very popular with students in capturing stimuli and helping them in the learning process, so that they can foster motivation in fun learning and maximum learning outcomes according to the desired needs.

The learning styles that will be discussed in this study are visual, auditory, read/write and kinesthetic (VARK) on Fleming's VARK learning styles and preferred learning modalities [16]. Learning modalities are divided into four components, namely visual, auditory, read/write, and kinesthetic which is abbreviated as VARK. Learning with a visual style means learning by relying on the senses of the eye through observation, demonstration, and the use of visual aids. Auditory is a learning style by listening, paying attention, speaking, presenting, giving opinions, ideas, responding and arguing. Read/write emphasizes learning styles by taking notes and reading. Kinesthetic is a learning style by moving, doing, and experimenting. Kinesthetic means body movement (hands on and physical activity). So that learning must experience and do. The VARK learning style assumes that learning will be effective [17], [18].

Achievement of the results to be examined in this study is the learning outcomes. According to Kiviniemi [19], there is an increase in student learning outcomes when using learning application media that combines text, images, and sound. The form of media relevant to this is called multimedia. This is because multimedia is able to present subject matter with an attractive presentation for all students. Some positive findings from empirical studies regarding the applied impact of multimedia in the learning process conclude that multimedia has the potential to improve the quality of the learning process and support the success of learning in the present and the future [20], improve critical thinking skills [21]–[24], as well as overcoming abstract material misconceptions.

Higher education requires an effective learning model in the learning process so that students obtain maximum learning results. The learning process at STIKOM Uyelindo so far, the learning material delivered through online learning media has the same concept (one size fits all) where lecturers present material without paying attention to student characteristics, each student has different characteristics in processing learning information. One of the characteristics identified is learning preferences. The learning preference measured in this research is the VARK preference. Therefore, we need a learning model that has adaptive capabilities, where the system can adjust learning content based on each student's learning style. Based on the survey conducted, research data was obtained which will be used as a reference in developing the adaptive educational hypermedia model applied at STIKOM Uyelindo. There were 78% of students who stated that lecturers only sent the same material via the learning website, which had an impact on the low number of students who understood the material presented, which only 23% of students understood the material presented and only 19% of students got the maximum score in solving questions according to the material presented.

In this study, AEHS was used to determine how much influence the achievement of learning outcomes had when it was associated with determining the VARK learning style. The division of VARK learning styles is carried out in an effort to group strategies based on the dominant learning style. Teaching materials will be adjusted based on learning styles that have been grouped previously with the form presented according to VARK. Where with the same material content but presented in different forms, namely images, audio, video and text forms. Therefore, a learning model is needed that is in accordance with the preferences of students and the level of knowledge in understanding the material presented and a learning model that can assist students in determining their own learning model.

2. METHOD

This research was conducted at STIKOM Uyelindo Kupang, Indonesia, involving 100 informatics engineering students as samples in the research [25]. This study uses a research and development (R&D) approach for interactive multimedia development models [26]. Research and development procedures include assessment/analysis, and then followed by design, development, implementation and evaluation. The needs analysis stage consists of two processes, namely needs analysis and front-end analysis.

The first stage of this research is research and analysis (assessment/analysis) which is divided into two processes, namely the stages of needs analysis (needs assessment) and front-end analysis (front-end analysis). Needs analysis in this study used the observation method. Preliminary analysis aims to obtain complete information regarding what will be developed in this study. The development process at the design stage prepares instruments or devices that will be used for the expert validation process and validation of student learning preferences. The development stage is the process of converting product specifications to the physical form of the product to be developed, in this case adaptive learning. The development stage includes making a storyboard as a guideline for developing a product which includes material input, interface design. The implementation phase includes validation from media experts and material experts, which then if the results are deemed appropriate then they are tested on students. The trials on students consisted of two activities, namely trials on small groups and trials on large groups. The evaluation stage is an evaluation process carried out by product developers focusing on product validity through media expert tests, material expert tests and the results of both small group trials and large group trials. The evaluation stage refers to the results of the validation that has been carried out previously.

In this development research using instruments in the form of: i) a questionnaire in the form of a learning style measurement instrument using the VARK questionnaire [27], [28]; ii) instructional media expert questionnaire; iii) instructional design expert questionnaire; and iv) questionnaire measuring student learning outcomes. Improvements from experts are used as input for the product being developed. The score acquisition data from learning media experts is the data that will be developed in this study. The data that has been collected is divided into two, namely quantitative data and qualitative data [29]. Qualitative data comes from suggestions given by learning media experts which will be analyzed descriptively. Meanwhile, quantitative data is analyzed based on percentage using (1). The criteria for the validity of learning media can be seen in Table 1. The product is declared feasible if it meets the very valid and valid categories.

$$V = \sum \frac{gain\ score}{N}\ x\ 100\% \tag{1}$$

where:
V =validity
$\sum$ =number of validator scores
N =max score

Table 1. Criteria for evaluating validity

Assessment criteria (%)	Category
81-100	Very valid
61-80	Valid
41-60	Enough
21-40	Less valid
0-20	Invalid

Increasing students' abilities in learning in development research is analyzed by determining the normalized gain score using (2). The normalized N-Gain score assessment criteria are divided into three categories, which can be seen in Table 2. The learning outcomes in this study were then processed based on the scores obtained in the posttest results to obtain the level of student learning ability. Learning outcomes are divided based on the level of understanding of both students who have VARK preferences.

$$Gain\ score = \frac{(Posttest\ average\ score)-(Pretest\ average\ score)}{(Maximum\ score)-Pretest\ average\ score} \quad (2)$$

Table 2. Determination of the gain score category [30]

No	Gain score	Category
1	≥0.7	High
2	0.3≤Gain score≤0.7	Currently
3	≤0.3	Low

3. RESULTS AND DISCUSSION

3.1. Design adaptive educational hypermedia system

The AEHS design process begins with creating a framework for the product to be developed. The product design process can be seen in Figure 1. The process of selecting AEHS content is set based on measurements of learning style preferences that have been carried out. Students who have a visual learning style will get content with visual models, auditory learning styles will get aural model content, read-write learning styles will get content with text or writing models, and kinesthetic learning styles will get content with simulation models. The intervention process was carried out by students to label based on the preferences of VARK students.

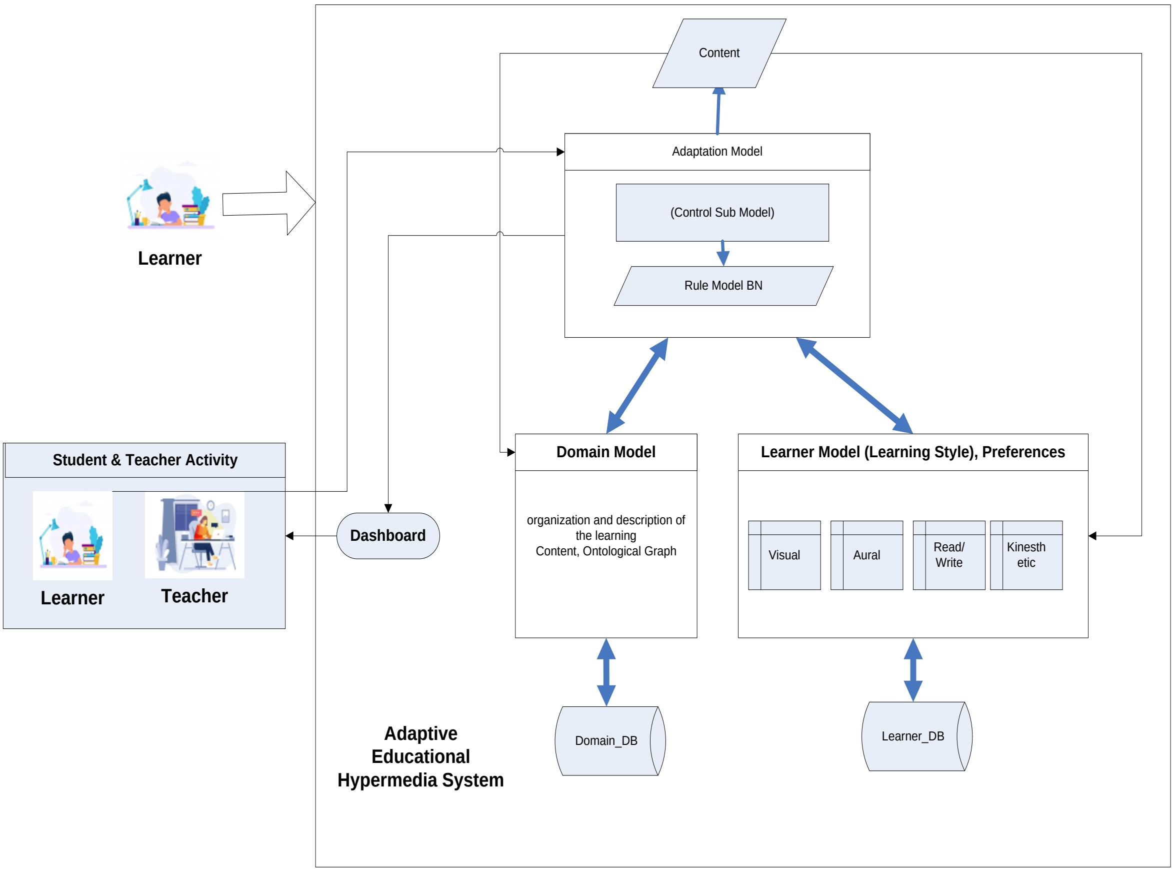

Figure 1. AEHS product development framework

3.2. Adaptive educational hypermedia system development results

In this study, an AEHS media was successfully created which was used to assist the online learning process for STIKOM Uyelindo Kupang students. The developed AEHS can be accessed via a web page or can be accessed via a mobile smartphone. The login navigation on the AEHS page is shown in Figure 2. Measurement of learning styles using the VARK questionnaire with the aim of measuring the learning styles possessed by students. The learning styles possessed by students become student profile data that can influence the flow of learning material in planned courses. AEHS allows students to get a mode or form of material that suits the needs of students based on their respective learning styles. The VARK questionnaire is presented in 16 question items where each question represents a tendency toward VARK learning styles, as shown in Figure 3. The process of filling out the questionnaire was taken by all students and then each question item was recorded on the AEHS dashboard. In Figure 4, the dashboard displays the results of measuring student learning styles, the results of achievements in the student learning process, the amount of material studied by students, and the percentage of scores obtained from the pre-test and post-test results.

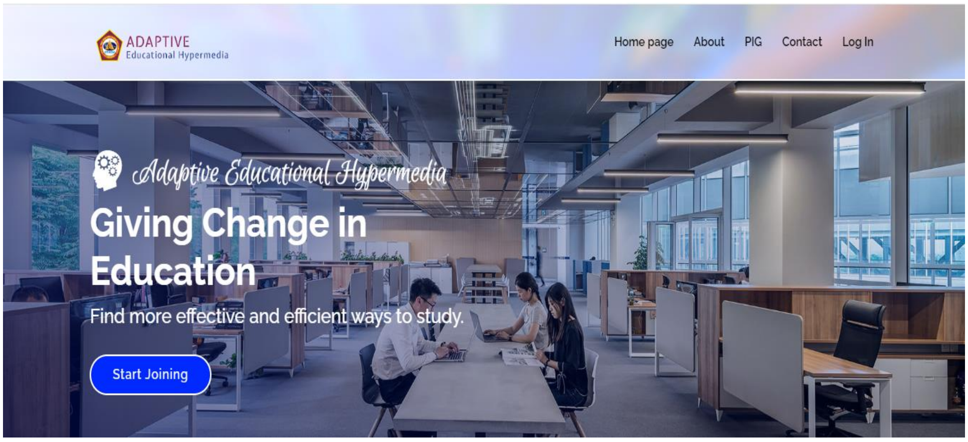

Figure 2. Login navigation on the developed AEHS home page

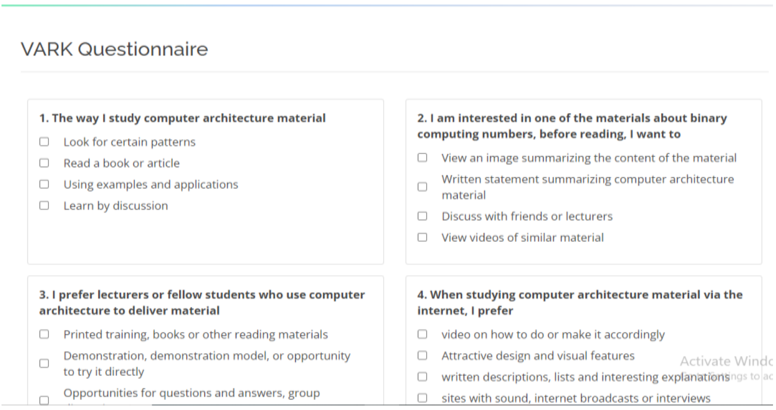

Figure 3. VARK questionnaire page

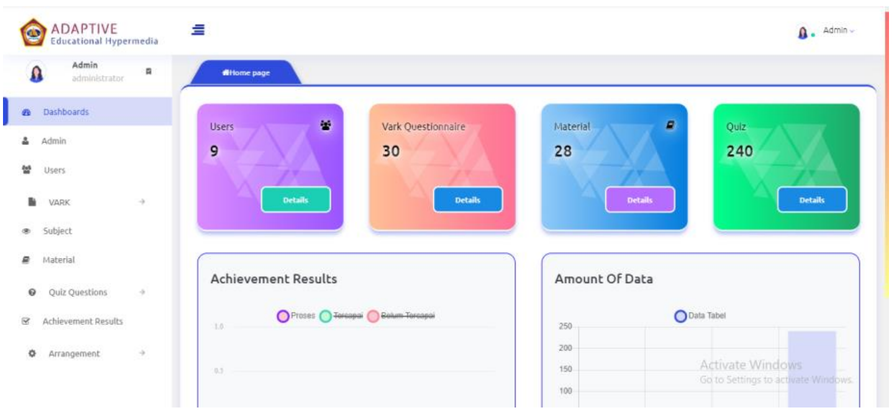

Figure 4. Dashboard of student learning style measurement results

3.3. Analysis of learning outcomes

Analysis of learning outcomes is carried out as a process to identify the extent to which students can solve the problems given at the end of the learning process. Analysis of learning outcomes consists of three parts, namely the level of difficulty for solving problems in learning, the amount of achievement of learning outcomes, and details of solving problems in measuring learning outcomes. The level of student difficulty in solving problems can be seen in Table 3 showing the average level of student difficulty in the process of completing learning material about computer architecture. Each student is given a number of questions related to problem solving in each chapter of learning material. The average student difficulty in solving problems can be seen in Table 3. While the average achievement of learning outcomes for Informatics Engineering students can be seen in Figure 5.

Table 3. The average student difficulty in learning the material

Category	Average difficulty level (%)
Introduction to computer architecture	16.25
Evaluation and computer performance	19.24
Memory	15.49
Data storage equipment	22.03

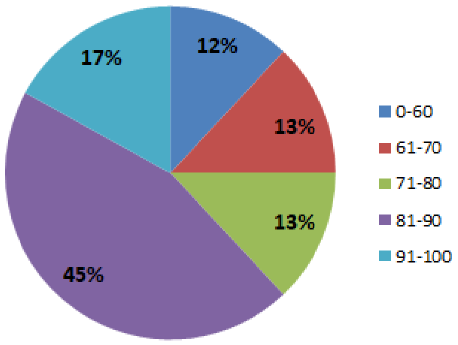

Figure 5. The average achievement of student learning outcome

3.4. Results of expert analysis of adaptive educational hypermedia system

The results of the expert analysis as a whole consist of expert analysis of learning instruments, analysis of learning media experts, analysis of learning design experts and validation of measurement of learning outcomes. The results of the analysis provide an overview of the developments that have been carried out in this study, as shown in Table 4. The table shows the results of the overall expert validation where the learning instrument expert validation obtains a score of 8 out of a maximum score of 8, or fulfills the "very valid" category. The learning media validation results obtained a score of 80 out of a maximum score of 84 or fulfilled the "very valid" category, the learning design validation results obtained a score of 44 out of a maximum score of 48 or fulfilled the "very valid" category. Whereas on the results of measurement validation measurement validation measurement of learning outcomes problem-solving ability obtains a score of 48 out of a maximum score of 52 or fulfills the "very valid" category.

Table 4. Expert validation

No	Subject	Score		Percentage (%)
		Score acquisition	Maximum score	
1	Expert validation of learning instruments	8	8	100
2	Learning media validation	80	84	95.24
3	Learning design validation	44	48	91.67
4	Validation of measurement of learning outcomes	48	52	92.31

3.5. Small group trial results

The first test phase of the study consisted of conducting experiments in small groups. For the results of the small group experiment, the paired sample t-test analysis technique was used. Paired sample t-test aims to determine the mean difference between the results of two paired groups (samples). The number of students in the small group test was ten people, as shown in Table 5. In Table 5, it can be seen that the pretest results have an average value (mean) of 54.783. While the posttest results have an average value (mean) of 83.116. The standard deviation shows an average data deviation of 9.53209 from the mean for the pretest results and an average data deviation of 6.99017 in the large group, in other words, the standard deviation is useful to describe how far the tested data varies. The mean standard error aims to measure the variation in existing data, where the result of the mean standard error in the pretest results is 3.01431 and in the posttest results is 2.21049. In measuring the correlation of paired samples, the correlation value between the pretest results and posttest results was 0.301, as shown in Table 6.

Table 5. Statistical measurements of paired samples in small groups

		Mean	N	Std. Deviation	Std. Error mean
Pair 1	Pretest	54.7830	10	9.53209	3.01431
	Posttest	83.1160	10	6.99017	2.21049

Table 6. Paired samples correlations

		N	Correlation	Sig.
Pair 1	Pretest and posttest	10	.301	.398

The results of small group t-test measurements show results related to whether the use of the AEHS learning model has an impact on learning outcomes. Significance value (2-tailed) or probability Sig. 0.000<0.05, so that in the group test it can be concluded that there is a significant difference between the results of the pre-test and the results of the post-test. The measurement results show that the AEHS learning model has an impact on the achievement of learning outcomes, as shown in Table 7. The increase in the value of learning outcomes in the small group test can be seen from the gain score calculated using (2) and the gain score is 0.735, or included in the high category.

Table 7. Results of paired sample t-test in small groups

		Paired differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% confidence interval of the difference				
					Lower	Upper			
Pair 1	Pretest-posttest	-28.333	9.97854	3.15549	-35.5	-21.19478	-8.979	9	.000

3.6. Summative evaluation test analysis

Summative evaluation is an assessment carried out after the completion of a program or learning process. Summative evaluation aims to measure learning outcomes, with this assessment helping lecturers know the level of development at the end of each student learning process because learning outcomes are a series of processes from the beginning to the end of the learning process. The summative evaluation test in this study used a comparative test between learning strategies with 100 participants, in the AEHS learning model (n=50) and the learning model using the web-based learning method (n=50). The first step before testing the summative evaluation data is to check the uniformity and normality tests on the data to be processed. The research data has three classes, namely preferences, gender, and the experimental group. The demographic information of students can be seen in Table 8.

Table 8. Student demographic information

Gender	Learning style	Learning model	
		AEHS	Web base learning
Male	Visual	17	
	Auditory	7	
	Read/write	5	
	Kinesthetic	1	
	Not identified		32
	Total	30	32
Female	Visual	8	
	Auditory	4	
	Read/write	6	
	Kinesthetic	2	
	Not identified		18
	Total	20	18

The research data is processed using a homogeneity test with the aim of knowing whether the variable data obtained is data that has a homogeneous variant. Analysts of summative evaluation tests use t-test analysis with the help of IBM version 22 of the statistical package for the social sciences (SPSS). In Table 9, it is known that the significance value (Sig.) of the learning outcome variable in the AEHS and web-based learning groups is 0.699. The significant value of learning outcomes is 0.699>0.05 so that it can be stated that the learning outcome variables in the AEHS and web-based learning groups have the same variance.

Table 9. Homogeneity of learning outcomes variants

Levene statistic	df1	df2	Sig.
0.150	1	98	0.699

After the homogeneity test and data normality test were carried out, the summative evaluation was tested using t-test analysis with the aim of finding out the differences between two paired groups of samples undergoing two different processing methods. Before carrying out the t-test, the first step is to carry out a homogeneity test using the Lavene test. Levene's test differentiates based on tendency: i) if the variances are the same, the t-test uses the assumption of equal variances; and ii) if the variances are different, the t-test uses the same variance without assumptions. In Table, 10 it can be seen that the learning outcomes in the AEHS model (n=50) have an average AEHS learning outcome of 78.9692, while the average learning outcome for web-based learning is 72.1176. The average exam score on AEHS is greater than the learning results for web-based learning. The probability (significance) P_{value} obtained is 0.150>0.05 so it can be stated that H_0 is accepted. Therefore, it can be concluded that the P_{value} probability value of 0.150 is greater than 0.05 so that the variance between the two class groups (AEHS and web-based learning) is the same, as shown in Table 11.

Table 10. Statistics for the AEHS group-web-based learning

	Learning model	N	Mean	Std. Deviation	Std. Error mean
Learning outcome	AEHS	50	78.9692	9.23410	1.30590
	Web-based learning	50	72.1176	8.47148	1.19805

Table 11. Independent samples test

		Levene's test for equality of variances		t-test for equality of means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean difference	Std. Error difference	95% confidence interval of the difference Lower	Upper
Learning outcome	Equal variances assumed	0.15	0.699	3.87	98	.000	6.85160	1.77	3.335	10.37
	Equal variances not assumed			3.87	97.9	.000	6.85160	1.77	3.334	10.37

3.7. Discussion

This research focuses on developing AEHS to improve the learning outcomes of engineering students at the STIKOM Uyelindo Kupang, where testing is carried out on students who use AEHS content and other e-learning systems to see the extent of changes in student learning outcomes. After testing the developed AEHS system, it showed a positive influence on student learning outcomes. This is in line with the results of previous research [31] stating that the AEHS learning approach is very effective, where learning outcomes can be influenced by character students used in the AEHS [32]. Several other studies show the effectiveness of using adaptive systems in the student learning process [33]–[35].

The AEHS product developed can be used to help universities carry out a more optimal learning process by using an adaptive hypermedia learning system [36] which is able to improve engineering student learning outcomes. The AEHS developed is able to detect student learning styles [37], [38] based on answers to the VARK questionnaire with 16 question items and recommend learning materials based on student learning styles. In the system being developed, there is a pre-test and post-test to measure the extent of students' understanding in studying the material presented by the system, so that it will have an impact on learning outcomes. Students can independently study the material according to their preferences and desires [39]. Lecturers as teachers can know the characteristics of students so they can provide material that suits students' learning styles. Based on the results of the trials carried out, there were differences in the average learning outcomes between students who were given adaptive hypermedia learning content and had better learning outcomes compared to the learning outcomes of students who used non-adaptive e-learning [40]. What this research hopes to achieve is that students are able to improve their learning abilities by utilizing the ease of content presented by the AEHS so as to obtain better learning outcomes. The AEHS developed is able to detect and recommend content or learning materials that suit the learning styles of engineering students. In this system students can learn more from one course. This system, which has been integrated with artificial intelligence, can be easily used by students and lecturers because it is designed to be user friendly.

4. CONCLUSION

In improving student learning outcomes, it is necessary to use a learning media that is in accordance with the learning character or learning style of informatics engineering students, such as the use of adaptive educational hypermedia system developed in this study is used to solve problems in the learning process. the use of learning media that can be accessed both through laptops and smartphones is needed by students today. Ratings from learning media experts (100%), instructional design experts (91.67%), learning instrument experts (95.24%), and learning outcome measurement experts (92.31) gave very good ratings for the development of AEHS media in this research. Increasing the value of informatics engineering students' learning outcomes in the small group test obtained a gain score of 0.735, or included in the high category.

Based on the results of the t test with the help of SPSS 22, it was obtained a significance level test using two sides (α=5%), where the risk of making a wrong decision to reject the true hypothesis was 0.05. Independent t test obtains t count of 3.87, the results of a comparison between t count and t table (df=98) and probability it can be concluded that the value of t count>t table (3.87>1.98477) and P_{value}<Sig (0.000<0.05) The results of the comparison state that there are differences in the average learning outcomes in AEHS with the average learning outcomes in web-based learning, the average learning outcomes achieved with AEHS are greater than using web-based learning strategies (78.9692>72.1176). It can be concluded that the use of learning style-based AEHS learning media is more effectively used to improve student learning outcomes of STIKOM Uyelindo Kupang informatics engineering compared to the use of learning strategies with web-based learning.

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