

# The Effectiveness and Efficiency of Using E-Learning in a Digital Learning Environment

Norfaridatul Akmaliah Othman<sup>1</sup>, Doni Purnama Alamsyah<sup>2\*</sup>, Johan Muliadi Kerta<sup>3</sup>,  
Doni Morika<sup>4</sup>, and Yudi Ramdhani<sup>5</sup>

<sup>1</sup>Department of Technology Management, Universiti Teknikal Malaysia Melaka, Melaka, Malaysia

<sup>2</sup>Entrepreneurship Department, BINUS Business School, Jakarta, Indonesia

<sup>3</sup>Computer Science Department, School of Computer Science, Jakarta, Indonesia

<sup>4</sup>Design Interior Department, School of Design, Jakarta, Indonesia

<sup>5</sup>Information System Study Program, Satu University, Bandung, Indonesia

**Abstract.** Human-Computer Interaction (HCI) supports the effectiveness and efficiency of using e-learning in a digital learning environment. Adapting technology to e-learning with the support of HCI is an important part of measuring e-learning effectiveness. This research aims to investigate how the implementation of HCI in digital learning affects the behavior of e-learning users. The study was carried out by testing a model that can support e-learning effectiveness with the support of technological factors, pedagogical factors, individual characteristics and instructor characteristics. The survey research method was carried out by collecting data using quantitative methods. Data was obtained through online questionnaires from students with experience with e-learning environments. The data was tabulated and processed using a linear regression approach with the SmartPLS statistical data processing tool. Hypothesis were developed to test and analyze the research model. The research results show that technological factors, pedagogical factors, instructor characteristics, and individual characteristics of e-learning users can increase e-learning effectiveness. Individual characteristics are the main factors that can control e-learning effectiveness. The research findings explained the importance of interaction from e-learning users in measuring the success of implementing HCI in e-learning. Universities, as providers of digital learning through e-learning, are deemed to pay attention to individual characteristics through face-to-face e-learning designs that are more effective and user-friendly.

## 1 Introduction

Human-Computer Interaction (HCI) appeared in 1960s with a focus on text-based interaction [1], currently used artificial intelligence in multimodal interactions [2]. HCI is useful in supporting user interaction performance with a platform, including implementation in a digital learning environment. User interaction with computers, cellphones and other digital platforms focuses on effectiveness and efficiency, so that the system on the platform is easy

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\* Corresponding author: [doni.syah@binus.ac.id](mailto:doni.syah@binus.ac.id)

and intuitive in line with user needs [3]. In the digital learning environment, HCI is implemented through the e-learning concept [1]. This study began with adapting e-learning technology for a more effective learning process and supporting student academic performance [4]. The presence of HCI brings awareness to the importance of interface design in supporting the effective use of e-learning in the campus environment.

A good learning experience supports student academic performance, in an online learning context, and therefore, effective interface support is needed [5]. E-learning as a digital learning option is closely related to the HCI concept, because the effective and intuitive interface design in e-learning supports a good learning experience for students [6]. Several factors that are taken into consideration regarding HCI in the e-learning concept include user interface design, usability, accessibility, interactivity, and user experience [5]. User experience is one of the most important factors related to the effectiveness of using e-learning and supporting student academic performance. User experience describes the user's experience in a digital learning environment, which can increase user engagement and learning retention [7]. Studies on user experience are closely related to e-learning effectiveness, this explains the importance of assessing factors that can support e-learning effectiveness [8]. In fact, e-learning effectiveness explains the extent to which user interactions in e-learning support learning objectives. Student involvement in digital learning is very important, including in the process of adapting e-learning technology [9]. Studies on e-learning effectiveness support understanding and practical application as a basis for evaluating HCI implementation. There are several factors that can support e-learning effectiveness, including technological support [10], user pedagogical factor [11], instructor characteristics [9] and individual characteristics [7]. Technological support factors are believed to influence e-learning usage behavior [12], so that they can support the learning process. E-learning user behavior is often studied from the adaptation process [13], because it relates to acceptance and the ability to use e-learning effectively. Technological factors are the technical aspects of using e-learning, requiring support from both hardware and software so that e-learning runs well. Users have an assessment of technological support factors, especially those related to accessibility, usability and experience [14]. In the e-learning concept, pedagogical factor explains the role of design, implementation and evaluation of the online learning process [15]. The satisfaction and experience of e-learning users largely depends on pedagogical value, where there are clear learning stages [16]. Pedagogical factors provide an understanding of the learning process, resulting in retention of students learning using digital learning [11]. The opportunity to achieve e-learning effectiveness through pedagogical factor is very large, considering that there is student involvement in the online learning process.

E-learning is an online learning platform, currently widely used by students at university level because it is considered more independent in the digital learning process [12,17,18]. In connection with independence, it is known as individual factor that support learning achievement [7]. Individual characteristics of e-learning users are perceived self-assessments in the digital learning process [19]. Students' self-efficacy is stated to support a good acceptance process for adapting technology, especially in self-learning using digital platforms. Individual characteristics are factor that can support learning outcomes and e-learning effectiveness [20]. There is other factor related to the human brain, namely instructor characteristics [21]. Even though the digital platform is an independent learning process, there is a choice of instructors who can help with the learning process. Good acceptance from instructors supports the effectiveness of using e-learning [22]. In line with the problem phenomena studied in this research, the research objective is to examine the factors that support e-learning effectiveness, which are technological support factor, pedagogical factor, individual characteristics and instructor characteristics. This research shows important stages of supporting HCI in the learning process using digital platforms.

## **2 Literature Review and Hypothesis Development**

Research reviews are carried out to analyze theory and theoretical support to develop the research hypotheses. This research focuses on the implementation and impact of HCI on digital learning. Previous studies related to the behavior of e-learning users revealed that there are several variables including technological support factor, pedagogical factor, individual characteristics, instructor characteristics and e-learning effectiveness. The final part of the literature review presents the development of research hypothesis as a model to guide this study.

### **2.1 Technological Support and Pedagogical Factors**

Technology in the e-learning concept act as a supporter to spread knowledge without limits and time [10]. Technology in digital learning, makes it easy for online learning systems. Technological factors are often associated with adaptation theory known as Technology Acceptance Model (TAM) [12], which was because of the process of using technology by users. It is hoped that e-learning users will be able to adapt easily, so that learning outcomes can be achieved. The key elements of TAM are related to perceived ease of use and perceived usefulness, which aims to evaluate the technology applied to the e-learning concept [13,23]. This explains the importance of technological factors in supporting digital learning environments. Current developments in technological factors test the readiness of technology, especially digital learning [24]. The theory presented is related to the readiness of e-learning users to use and utilize digital platforms as learning media. There are clear measures for assessing technological factors, including easy access, experience problems, browsing speed, easy to use, well structured, useful features, and pleasant design [25,26]. Previous studies explain that technological factors are important in supporting the learning process through digital platforms.

There is a second factor that supports the digital learning process, namely the implementation of learning methods and practices. Pedagogic is a factor that clearly explains the learning process and its support [11], so that learning outcomes can be determined. There are instructions and learning methods that every student needs to understand, especially in online learning where there is technology support [27]. In general, it is explained that pedagogical factors are support for the arts and methods of teaching and education [26]. When related to e-learning, the pedagogical in question is the art and online learning methods that need to be adapted by students [15]. There is interaction between instructors and students in the learning process, so that pedagogy occurs [16]. Through e-learning, there is another thing involved, namely technology as part of the digital learning platform. Pedagogical factors can be evaluated by students through several indicators, including under stable content, updated content, accurate content, organized content, relevant content, usefulness content, understanding learning, quick exchange and positive environment [15,26,27]. Support from pedagogical factors is important in the learning process through e-learning, so it is often studied, especially at the teacher level, in collaborating with technology for a more effective learning process.

### **2.2 Individual and Instructor Characteristics**

The learning process through digital platforms provides every student with the opportunity to learn without being limited by time and place [13]. However, individual abilities are needed to adapt to technology, because e-learning is part of self-learning [28]. Individual characteristics are aspects of individuals as e-learning users [20], meaning that there are individual abilities needed to support learning through e-learning. Individual factors in e-

learning are also known as online user behavior, where there are different characteristics in adaptation to digital platforms [29]. In general, individual characteristics are described as user behavior that has different behavior and can influence interactions with technology [20]. Individual factors support the adaptation process in e-learning, because they are related to learning style, motivation, self-efficacy, and personal abilities in new technology [30]. Often individual characteristics relate to cognitive theory, because of the user's ability to solve the problems faced independently [30]. Individual characteristics can be evaluated by students through several indicator questions including like new technology, like to use first, have necessary skills, confidence with instructor, confidence to use alone, trust to quality, trust to security, and trust to knowledge [20,26]. The higher the individual characteristics in the independent learning process through digital platforms, the better it is at supporting academic performance achievements through e-learning [31].

Learning achievements cannot be separated from instructor's support, in this case as a mediator of knowledge transfer [9]. Without instructors, students often misunderstand the knowledge they receive [32]. Instructors are an important factor in supporting the delivery of knowledge from e-learning [33]. Instructors' characteristics are related to the attributes of abilities, skills and quality in the e-learning concept [9]. Instructors can increase the effectiveness of learning through e-learning, because they act as leaders in the learning process [32]. The presence of instructors can support students' motivation and learning performance online, this can be seen from educational leadership theory [33]. Inspirational instructors are the key to the online learning process [9]. It is important to assess instructors' characteristics, so there are many studies, especially in relation to sustainable learning styles. In general, it is known that instructors' characteristics can be assessed from several questions including interest material, friendly, seeking advice, receiving answers, handling technology, helpful, explained well, feedback, and encouraged [22,25]. In digital learning, instructors can support the effectiveness of learning, making it easier to find learning outcomes [22].

### **2.3 E-Learning Effectiveness**

Effectiveness theory is often used in various fields of science, including education [8]. Effectiveness measures success, in the context of e-learning, so effectiveness explains the success in student adaptation to e-learning in supporting academic performance [9]. In effectiveness theory there are frameworks and concepts that are used in evaluating performance, in this case the framework and concepts of e-learning [24]. So that e-learning effectiveness can be conveyed as students' understanding of digital learning more effectively. E-learning effectiveness is the goal in this research, which is known to be assessed from several indicators including easy use, adequate, understand, contribute, discussion, and valuable [25,34,35]. Studies on e-learning effectiveness are often carried out mainly in relation to continuous evaluation approaches [35]. This aims to repair and improve the system that has been used, especially the e-learning learning concept [8].

### **2.4 Hypothesis Development**

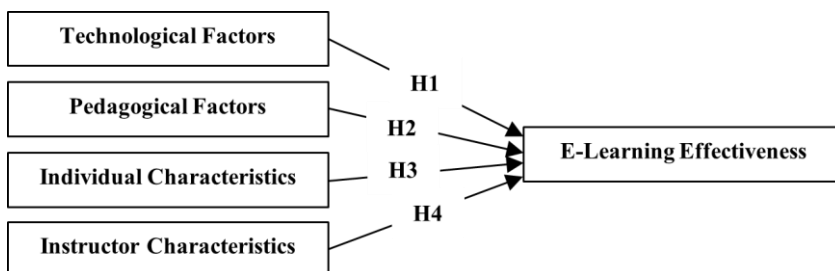
The goal of this research is e-learning effectiveness, which is studied by users, namely students. In connection with HCI, e-learning effectiveness measures students' understanding and experience when interacting with digital learning [1]. Previous research studies explained that there are several factors that can support the achievement of e-learning effectiveness. Firstly, it is said that technological factors are the main support, because e-learning cannot be separated from the use of technology [26]. The readiness of supporting technology can improve e-learning performance and the effectiveness of its use [36]. Technology transfer in e-learning is the right thing to use, because technology support in education is not something

new but something that is required to exist [13]. This means that the implementation of e-learning occurs because of good technological support. Apart from technology, it was found that there was an impact of the e-learning learning process on learning outcomes. It is said that pedagogical factors are the main support for the process of accepting online learning [11]. Clear pedagogical support is the main means of good adaptation to e-learning [27]. Students can experience a planned learning process through the support of pedagogical factors [26]. In line with previous research studies, it appears that the effectiveness of e-learning can be influenced by two factors, including technology and pedagogy, so the following is a draft hypothesis for this research.

- Hypothesis 1 Technological factors is positive correlation to increase the e-learning effectiveness
- Hypothesis 2 Pedagogical factors is positive correlation to increase the e-learning effectiveness.

HCI is related to the evaluation of e-learning users, in this case students and instructors [2]. This study focuses on user behavior, so that students as individuals have a role in achieving e-learning effectiveness [8]. In previous research studies, it was explained that individual characteristics are important factors that can assess e-learning adaptation [31], so that the effectiveness of using e-learning can be evaluated. In another study, it is confirmed that there is an impact of individual students on online learning outcomes [20], which means that the effectiveness of e-learning depends on the user's understanding. A study highlights the importance of the individual's process of adapting to new technology, especially in e-learning [12]. This aims to support the process of absorbing knowledge in e-learning. In line with previous studies, it implies that e-learning effectiveness can be influenced by individual characteristics. Users of e-learning who can help the learning process are instructors [9]. In fact, the role of instructors in e-learning learning outcomes cannot be denied [32]. This was explained in a previous study on the role of instructors on learning effectiveness [37]. In line with previous research studies, the individual and instructors' characteristics are an important part in measuring e-learning effectiveness. The following is the additional research hypothesis.

- Hypothesis 3 Individual characteristics is positive correlation with e-learning effectiveness.
- Hypothesis 4 Instructor characteristics is positive correlation with e-learning effectiveness.



**Fig. 1.** Hypothesis Model Development.

### 3 Methods

This study focuses on online learning behavior as part of HCI. The variables in this research have been explained in the literature review, including technological factors, pedagogical factors, individual characteristics, instructor characteristics and e-learning effectiveness. Each variable is measured with different measurements, there are seven indicators that map to technological factors. In pedagogical factors there are nine indicator questions, while for individual characteristics it is built by eight indicator questions. Followed by instructor characteristics, which includes nine indicator questions, and there are six indicator questions for evaluating e-learning effectiveness. Each indicator question is delivered to respondents via an online questionnaire with predetermined answers, a value of "1" for the answer criteria strongly disagree to "5" for the answer criteria strongly agree, in line with the Likert Scale approach theory. The research stages begin with data processing, research instrument testing, research hypothesis testing, analysis of research findings and recommendations for further research.

The research method utilized a survey of 547 respondents who filled out questionnaire perfectly. Respondents are among universities students from city of Bandung, Indonesia, who had previous experience with e-learning. The data was tabulated and processed using SmartPLS with two tests, first the PLS Algorithm to determine the relationship between variables and test the research instruments, secondly Bootstrapping to determine the path coefficient and test the research hypothesis [38,39]. The analysis and discussion in the next section were made based on the research hypothesis developed earlier.

### 4 Result and Discussions

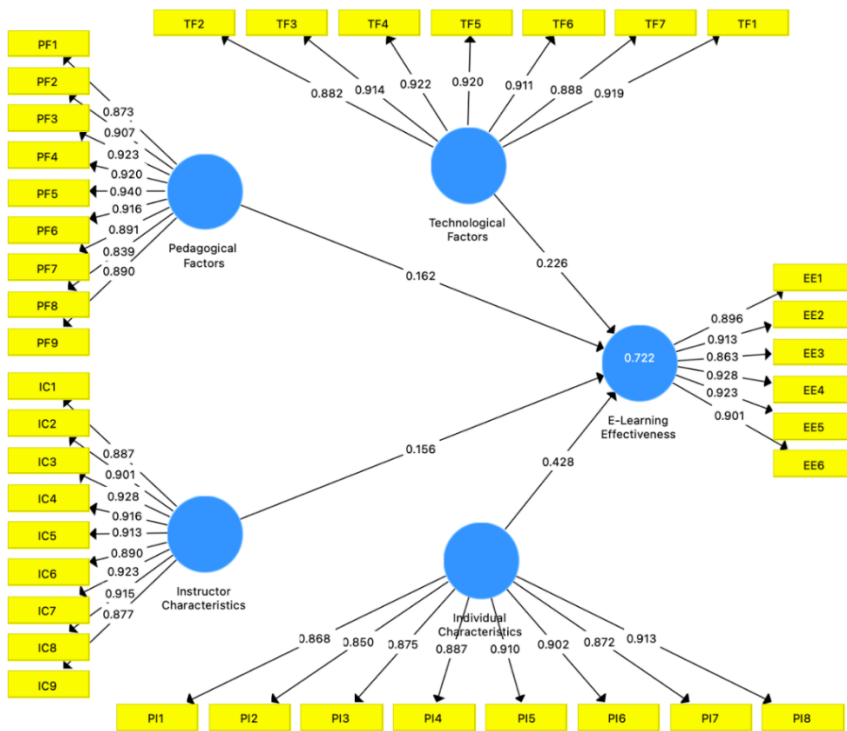


Fig. 2. PLS Algorithm Model Result.

Based on the data collection, respondents mostly students live in Bandung City (87.3%), meaning that e-learning users are not far from their respective campuses. The status of students was in the second semester as much as 49.7% and as many as 49.1% in the fourth semester. This finding was due to the distribution of the questionnaires in the current even semester in 2024. The majority have sufficient experience in understanding the concept of e-learning. Data processing was carried out first with the PLS Algorithm test, the test results appeared to explain all variables positively supporting e-learning effectiveness (Fig. 1). Next, research instruments tests were carried out and based on the test results, it appeared that all instruments were acceptable with values above 0.7 (Table 1) [40]. The instrument test was carried out by evaluating Cronbach's Alpha, rho\_A, Composite Reliability and Average Variance Extracted (AVE). The next statistical data test is through the Bootstrapping process, the test results appear in Table 2 and Table 3. The next instrument test is presented in Table 2, with an evaluation of all research instruments with latent variables. The test results show that all Outer Loading values are accepted considering that the P Value meets the criteria (<0.050) [41], so it can be explained that the research instrument test on the hypothesis model that has been designed can be analysed further.

**Table 1.** Instrument validity and reliability test result.

Instruments	Cronbach's Alpha	rho_A	Composite Reliability	Average Variance Extracted (AVE)
Technological Factors	0.965	0.965	0.971	0.825
Pedagogical Factors	0.971	0.971	0.975	0.811
Instructor Characteristics	0.973	0.973	0.976	0.820
Individual Characteristics	0.960	0.962	0.967	0.783
E-Learning Effectiveness	0.955	0.956	0.964	0.818

**Table 2.** Outer loading test result.

Instruments	T Statistics	P Values
TF1 <- Technological Factors	90.769	0.000
TF2 <- Technological Factors	55.025	0.000
TF3 <- Technological Factors	75.877	0.000
TF4 <- Technological Factors	74.802	0.000
TF5 <- Technological Factors	90.610	0.000
TF6 <- Technological Factors	75.966	0.000
TF7 <- Technological Factors	54.737	0.000
PF1 <- Pedagogical Factors	51.744	0.000
PF2 <- Pedagogical Factors	71.875	0.000
PF3 <- Pedagogical Factors	87.114	0.000
PF4 <- Pedagogical Factors	80.754	0.000
PF5 <- Pedagogical Factors	113.507	0.000
PF6 <- Pedagogical Factors	78.318	0.000

Instruments	T Statistics	P Values
PF7 <- Pedagogical Factors	53.752	0.000
PF8 <- Pedagogical Factors	35.911	0.000
PF9 <- Pedagogical Factors	57.987	0.000
PI1 <- Individual Characteristics	51.133	0.000
PI2 <- Individual Characteristics	43.615	0.000
PI3 <- Individual Characteristics	51.415	0.000
PI4 <- Individual Characteristics	64.664	0.000
PI5 <- Individual Characteristics	78.545	0.000
PI6 <- Individual Characteristics	65.497	0.000
PI7 <- Individual Characteristics	46.347	0.000
PI8 <- Individual Characteristics	58.316	0.000
IC1 <- Instructor Characteristics	54.321	0.000
IC2 <- Instructor Characteristics	61.939	0.000
IC3 <- Instructor Characteristics	94.438	0.000
IC4 <- Instructor Characteristics	71.879	0.000
IC5 <- Instructor Characteristics	52.025	0.000
IC6 <- Instructor Characteristics	51.151	0.000
IC7 <- Instructor Characteristics	63.217	0.000
IC8 <- Instructor Characteristics	71.290	0.000
IC9 <- Instructor Characteristics	36.241	0.000
EE1 <- E-Learning Effectiveness	68.848	0.000
EE2 <- E-Learning Effectiveness	72.922	0.000
EE3 <- E-Learning Effectiveness	38.972	0.000
EE4 <- E-Learning Effectiveness	92.226	0.000
EE5 <- E-Learning Effectiveness	86.720	0.000
EE6 <- E-Learning Effectiveness	48.609	0.000

**Table 3.** Path coefficient result.

Hypothesis	T Statistics	P Values
Hypothesis 1: Technological Factors -> E-Learning Effectiveness	4.510	0.000
Hypothesis 2: Pedagogical Factors -> E-Learning Effectiveness	3.264	0.001
Hypothesis 3: Individual Characteristics -> E-Learning Effectiveness	7.189	0.000
Hypothesis 4: Instructor Characteristics -> E-Learning Effectiveness	2.987	0.003

The results of the hypothesis test are clearly supported, from Table 3 it is known that all P Values meet the criteria (<0.050). The essence of the hypothesis test confirms that e-learning effectiveness can be controlled by several supporting factors including technological factors, pedagogical factors, individual characteristics, and instructor characteristics.

The research findings explain that technological factors are positively related to e-learning effectiveness, it is known that the correlation value is 0.226 (Fig. 2). This is in line with the results of the hypothesis test (H1) which confirms the significant impact of technological factors. Based on the previous research, it can be concluded that new technology in e-learning needs to be adapted well by users to achieve learning (effectiveness) [26]. In addition, support from technology is important in digital learning, including

achieving effectiveness. There are other factors that have a positive relationship with e-learning effectiveness, conveyed by pedagogy as a learning process with a positive correlation of 0.162 (Fig. 2). The results of the research model were confirmed by hypothesis testing (H2), where the P Value was obtained according to the criteria. It can be concluded that pedagogical factors are a variable that can change e-learning effectiveness. Previous studies have been carried out with similar results [27], in e-learning studies conveying the importance of pedagogy as a measuring tool for assessing the learning process, including its effectiveness and efficiency.

E-Learning effectiveness is part of the study of online learning behavior, therefore, it is related to user behavior such as individual characteristics. In the research findings, it was stated that there was a positive correlation of individual characteristics on e-learning effectiveness of 0.428. The results were confirmed by the P Value test (Table 3) where the hypothesis was accepted (H3). The essence of this part of the research is in line with previous expert studies, especially studies related to e-learning [12]. It was stated that the individual factor of e-learning users is an important factor in supporting the level of success of e-learning implementation. The abilities and experience of e-learning users explain the performance achievements of e-learning including its effectiveness. Assessing the effectiveness of e-learning is known through the support of the instructor in it. It is known from the research results that instructor characteristics play a role in increasing e-learning effectiveness with a correlation value of 0.156 (Fig. 2). The results of these findings can be confirmed by the results of the research hypothesis test (H4), where the P value matches the criteria with supporting information for the hypothesis. If we examine the analysis of previous research, it appears that there is something in line [37], which emphasizes the role of the instructor in the learning process, including e-learning.

The results of the analysis based on the PLS Algorithm (Fig. 2) explained the positive relationship of latent variables on e-learning effectiveness. It is known that the impact of each different variable is large which confirms the priority level of the impact of user behavior on e-learning effectiveness. The study of e-learning user behavior is part of human-computer interaction, which emphasizes the importance of understanding user desires to improve e-learning performance which is known through the level of effectiveness of use.

## **5 Implication, Conclusion and Recommendations**

This study demonstrated that HCI can improve the quality of learning, hence it is reflected to the concept of e-learning. The research objective focuses on e-learning effectiveness, this is in line with the benefits of the field of HCI science, namely increasing efficiency in managing and teaching e-learning systems. Universities as providers of online learning services can create e-learning environments that are more effective in achieving learning goals.

The results of the research explained that there are two factors that have a positive relationship in increasing e-learning effectiveness, namely technological factors and pedagogical factors. Technological factor is the priority because this variable has a better impact in changing the effectiveness of e-learning. Apart from that, the finding stated that there is a positive relationship between e-learning user behavior, namely individual characteristics and instructors' characteristics on e-learning effectiveness. Individual characteristics have a greater impact than instructors, so more attention is needed to the ability and experience factors of e-learning users. This is in line with the goals of human-computer interaction, where user experience plays an important role in increasing the effectiveness and efficiency of using digital platforms. This research has several limitations. Firstly, the characteristics of respondents are not divided based on the student's scientific and non-science fields. The supporting abilities of students have different attitudes towards accepting technology. Both studies only examined two technological and pedagogical

factors, it would be better for further research to examine other factors related to HCI such as motivation and emotional support. It is hoped that further research can be focus on the impact and benefits of HCI on the concept of e-learning.

“This work is supported by Bina Nusantara University and Universiti Teknikal Malaysia Melaka as a part of Bina Nusantara University’s BINUS International Research - Applied entitled ‘Human Computer Interaction in E-Learning: The Analysis of Student Performance’ with contract number: 069C/VRRTT/III/2024 and contract date: March 18, 2024.”

Data availability:

<https://zenodo.org/records/12741331>.

Author contributions:

**Norfaridatul Akmaliah Othman**: Conceptualization, Formal analysis, Investigation, Writing - Original Draft, Supervision and Funding acquisition. **Doni Purnama Alamsyah**: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Resources, Data Curation, Writing - Original Draft, Writing - Review & Editing, Supervision and Funding acquisition. **Johan Muliadi Kerta**: Writing - Original Draft, and Supervision. **Doni Morika**: Writing - Original Draft, and Supervision. **Yudi Ramdhani**: Writing - Original Draft and Supervision.

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