Strategies to Improve the Quality of Educational Environments: An Evaluation of the Student Center Building at the Diponegoro University, Semarang, Indonesia

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Abstract

Current developments are focused on energy efficiency to support sustainability. There are many indicators. One of the indicators can be investigated through the design evaluations of existing buildings. Reading and evaluating existing designs will help in adjusting the next design.

This paper presents a design evaluation for a student center building at Diponegoro University, Semarang, with a focus on energy efficiency readings. It uses qualitative methods involving quantitative calculations obtained through energy efficiency evaluation software. It uses case studies to generate detailed data for tracking energy efficiency as the focus of design evaluation. Data collection techniques include observations and questionnaires to ascertain how the existing buildings are used and perceived by the users.

The findings of this study include reviewing the shape of the building, the ratio of openings and the ventilation system of the building to increase energy-saving capabilities, evaluation of facilities such as open study rooms, study rooms, cafes/food services, roof gardens, and open spaces as well as reviewing the aesthetics of the student center building or facilities based on the physical opening. These three aspects can be used as references in a student center development design strategy for implementing energy efficiency in the future. The paper also shows how the strategy of producing a good educational environment can be accomplished through reading the existing environment as a basis for further design development.

Keywords: Sustainability, environment quality, efficiency energy, student centre, evaluation design.

Introduction

Energy efficiency is one of the issues discussed in many fields related to sustainable development. In architectural discourses, various building types are analyzed to obtain energy efficiency guidelines applied to their designs (Franco et al., 2023). One of the building types that are often the focus of energy efficiency is educational buildings because they need a good quality environment to increase learning and concentration of the students (Abdollahzadeh et al., 2023; O'Donovan & O'Sullivan, 2023). The correlation between architectural elements and environmental quality and the impact of the proposed solutions on energy use is also one of the energy efficiency strategies that need to be considered in the current conditions (Abdollahzadeh et al., 2023). Examining an educational building that considers energy efficiency is useful in supporting a healthy environment in order to realize sustainability.

This paper aims to present the results of an inquiry into energy efficiency in an existing building to obtain guidelines for the development of new buildings. The study examines various aspects related to energy efficiency in existing buildings in Indonesia in order to obtain findings that can be used during the development of a new building. This is a strategy for developing new buildings based on design evaluations. The case study is the student center building developed based on the Universitas Diponegoro (Undip) master plan. The Universitas Diponegoro, located in Semarang, Central Java, is one of the best campuses in Indonesia. This makes the number of students continue to increase every year and the student center facilities are an important part of it. The production of a learning environment with good acoustic quality, thermal comfort, air quality and visuals is a goal of the Universitas Diponegoro.

This paper is the beginning of the preparation of a design development program and is important to support sustainable architecture because the design focuses on energy efficiency. Based on PMWA (regulations issued by the board of trustees) Undip No 7 of 2016, concerning the Diponegoro University General Policy for 2015-2039. Undip is expected to become a World Class University in 2039, and the main thing is campus infrastructure. Currently, infrastructure assets are being addressed and continue to be maintained. One of them is the Student Center. This building has been established since 2012 and is in the maintenance and development stage. According to the Regulation of the Board of Trustees of the Diponegoro University Number 07 of 2016, the General Policy of Diponegoro University for 2015-2039, underlines the importance of developing the Undip campus (2020-2025) which should be designed based on the concept of green and sustainable architecture. This paper argues that developing a student center based on the findings of the design evaluation of an existing building by focusing on energy efficiency can support the Undip policy.

A Review of Literature

Many previous research has discussed improving environmental quality. Franco et al. (2023) argue that energy efficiency discourses through qualitative calculations with various experiments and applications are the current discourse, but discussions through evaluating existing buildings are rare. This research examines the strategies to improve the quality of environments through design evaluation, especially in the educational environment. According to Preiser (1995), design evaluation is a strategy to improve building quality to support sustainability. This paper attempts to describe strategies to improve the quality of the environment as a sustainable concept through a design evaluation.

The paper starts from a discourse on sustainability, especially in presenting an educational environment that can present an atmosphere that can increase creativity. The quality of a good educational environment can be enhanced through environmental quality. One of the strategies to maintain environmental quality is to present buildings that have energy efficiency.

Various discussions related to presenting sustainable buildings have been widely presented before. Franco et al. (2023) state that sustainability is related to energy. It is supported by Kartikasari et al. (2018). Meanwhile, Datey (2023) and Walker & Salt (2006) argue that sustainability is related to ecology. Dixon (2007) and Southworth (2016) associate it with liveability. This paper sees a gap in seeing sustainability through evaluating existing buildings. It argues that sustainability, especially in the educational environment, can be presented by reading about existing buildings as part of the future building developments. The method used for the evaluation of existing buildings is to assess sustainability through design evaluation.

Design evaluation is a medium used to improve the quality of building performance on an ongoing basis (Preiser, 1995). It is defined as a structured process for evaluating a building after the building is occupied (Menezes et al., 2012). Design evaluation becomes a measuring tool for the quality of a building when it has been built. Measurements pay attention to three aspects: technical evaluations, functional evaluations and behavioral evaluations (Snyder & Catanese, 2005). This paper argues that conducting a design evaluation on existing buildings can be a starting point in compiling a building development program. Design developments that continue to demand sustainability by presenting green buildings can be achieved through reading the various elements that have existed before. This certainly supports SGD 2030 point 7 (Union, 2017). However, Shao et al. (2018) and Susanti et al. (2020) point out that building development programs based on existing conditions cannot be separated from the previous readings on building uses. The way in which the existing buildings, especially related to energy efficiency function can be a form of developing a new building planning program that supports a sustainable concept.

This paper identifies the existing buildings from various aspects including functionality, usability, facilities and energy efficiency as an initial part of preparing a new building design development program. Facade elements are one of the aspects that are considered, because the outer shape of a design element is a form of socio-cultural symbolism that is different (Monga & Das, 2015). It starts with tracing how an existing building is inhabited and perceived by people. After that, the paper calculated the energy efficiency of the existing building and conducted a precedent study to get a new programming picture for the student center. It functions as a multi-purpose building, expected to have a flexible layout and produce comfortable conditions for various activities (Sawasdee & Phiboon, 2016).

Research Methodology

This study uses a qualitative method infused with several quantitative calculations obtained through energy efficiency evaluation software. To obtain optimal results in the preparation of the new building programs, it uses case studies as an identification model. As Cresswell (2009) says, the case studies allow a more detailed search, and this research requires an appropriate result. Thus, the case study method is chosen. The selected case study is in accordance with the plan to develop a new building in the Diponegoro University Environment, namely the Undip Student Center.

Data collection techniques used observations and questionnaires to ascertain how the existing building is used and perceived by the people. Data collection using a questionnaire was carried out to investigate user satisfaction related to quality of space. Questionnaires were distributed to Undip students who often use the Student Center for activities. They were randomly distributed to 100 respondents who came to the student center in August-September 2022. This method is usually used in design evaluation research that focuses on the energy efficiency of existing buildings (Franco et al., 2023; Hasila et al., 2020; Kartikasari et al., 2018).

The research begins with a survey at the case study location to get an overall picture related to the form and use of the student center. A questionnaire was then prepared to obtain data related to the opinions of student center users. Questions are structured to obtain data related to energy efficiency. The questions are related to lighting, ventilation and open spaces. The purpose of this research is to evaluate the design, and therefore additional questions related to visuals or the shape of the building and facilities are also included in the questionnaire. Questions are prepared using a multiple-choice model where the percentage of answers can be calculated directly in order to get accurate results.

In addition, this study also uses EDGE (Excellence in Design for Greater Efficiency) software to calculate the energy efficiency of the existing buildings. This software is one of the tools used for energy efficiency calculations that support green building and sustainability (Kartikasari et al., 2018). The calculation is done by re-drawing the existing building and entering indicators related to size, dimensions and orientation of the building. Energy-saving calculations in this study focus on the window-to-wall ratio (WWR) for lighting calculations. The ratio and comparison of the size of the window and the outer surface of the building are calculated by entering the size in the EDGE software. Meanwhile, the calculation of ventilation efficiency involves the position of windows and the width of the building.

Findings

The questionnaire measuring the level of user satisfaction consists of six parts: biodata, questions about lighting, ventilation, building visuals, open spaces, and facilities. The questionnaire was filled in by 100 respondents who were active students at Diponegoro University. The results of the user satisfaction questionnaire survey are as follows:

Table 1: Lighting aspect survey results
Source: Author

NO	QUESTION	EXPLANATION	PERCENTAGE
1.	I feel comfortable sitting .... the window of the Undip Student Center Room because it is bright	Near	51.4%
		In the middle of	36.4%
		Far from	12.1%
2.	I feel comfortable in the Undip Student Center Room when the window is .... because it is bright.	Open	84.1%
		Closed	15.9%
3.	I feel comfortable with the intensity of natural lighting when the Undip Student Center building faces	North	33.6%
		East	33.6%
		South	23.4%
		West	9.3%
4.	I feel comfortable with the artificial lighting intensity of .... lux in the Undip Student Center room.	200	71%
		500	15%
		1000	14%
5.	I turned on the lights during the day when I was at the Undip Student Center	Yes	20.6%
		No	79.4%
6.	I feel comfortable doing activities with warm colored lights at the Undip Student Center	Warm	9.3%
		Neutral	77.6%
		Cold	13.1%

Table 2: Ventilation Aspects Aspect Survey Results
Source: Author

NO	QUESTION	EXPLANATION	PERCENTAGE
1.	I feel comfortable in a space with… ventilation.	Opposite	71%
		Adjoining	17.8%
		One-plane	11.2%
2.	I feel more comfortable when the windows are open (Air sources: vents and windows)	Very cofortable	41.1%
		Comfortable	55.1%
		Uncomfortable	3.7%
		Very uncomfortable	0%
3.	I feel more comfortable when the window is closed (Air source: vent only)	Very cofortable	4.7%
		Comfortable	32.7%
		Uncomfortable	56.1%
		Very uncomfortable	6.5%
4.	I feel comfortable when the air temperature can be controlled	Very cofortable	51.4%
		Comfortable	48.6%
		Uncomfortable	0%
		Very uncomfortable	0%
5.	I feel more comfortable when the air conditioner is on	Very cofortable	55.1%
		Comfortable	44.9%
		Uncomfortable	0%
		Very uncomfortable	0%

Table 3: Visual building aspects aspect survey results
Source: Author

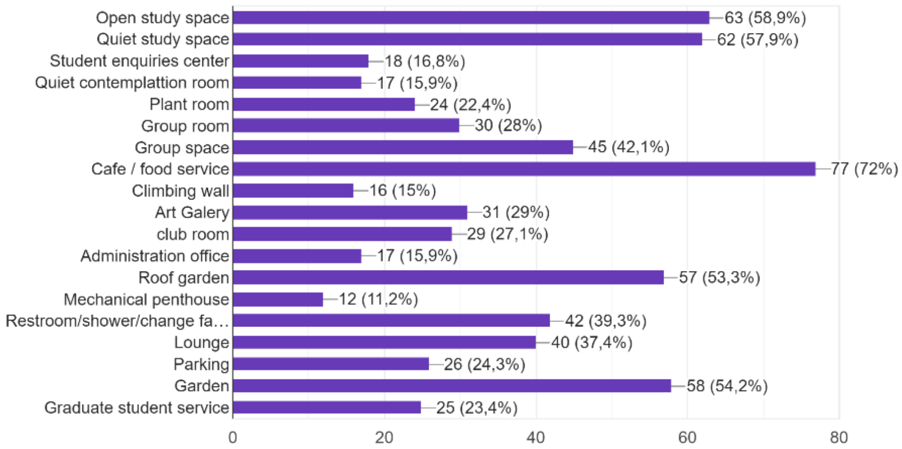
NO	QUESTION	EXPLANATION	PERCENTAGE
1.	I find the front facade of the Undip Student Center Building is attractive	Very attractive	3.7%
		Attractive	40.2%
		Unattractive	52.3%
		Very unattractive	3.7%
2.	I feel that the overall appearance of the Undip Student Center Building is attractive	Very attractive	3.7%
		Attractive	53.3%
		Unattractive	40.2%
		Very unattractive	2.8%
3.	I feel the shape of the Undip Student Center Building is attractive	Very attractive	5.6%
		Attractive	57%
		Unattractive	36.4%
		Very unattractive	0.9%
4.	I feel the shape of the building reflects its function of the building	Very reflective	10.3%
		reflective	60.7%
		Unreflective	29%
		Very unreflective	0%
5.	I feel that the shape of the building reflects the characteristics of its users	Very reflective	6.5%
		reflective	49.5%
		Unreflective	43%
		Very unreflective	0.9%

Table 4: Open Space Aspects Aspect Survey Results
Source: Author

NO	QUESTION	EXPLANATION	PERCENTAGE
1.	I feel that the availability of green open space (parks, green areas, etc.) at the Undip Student Center is sufficient	Very sufficient	2.8%
		Sufficient	31.8%
		Insufficient	57%
		Very insufficient	8.4%
2.	I find the Undip Student Center's green open space is attractive	Very attractive	3.7%
		Attractive	21.5%
		Unattractive	68.2%
		Very unattractive	6.5%
3.	I feel that the availability of non-green open spaces (outdoor facilities) at the Undip Student Center is sufficient	Very sufficient	11.2%
		Sufficient	58.9%
		Insufficient	29%
		Very insufficient	0.9%
4.	I find the non-green open spaces of the Undip Student Center are attractive	Very attractive	3.7%
		Attractive	33.6%
		Unattractive	58.9%
		Very unattractive	3.7%

- Facility

What facilities need to be in the Undip Student Center, which currently does not exist? (can choose more than one)



What facilities need to be improved at the Undip Student Center? (can choose more than one)

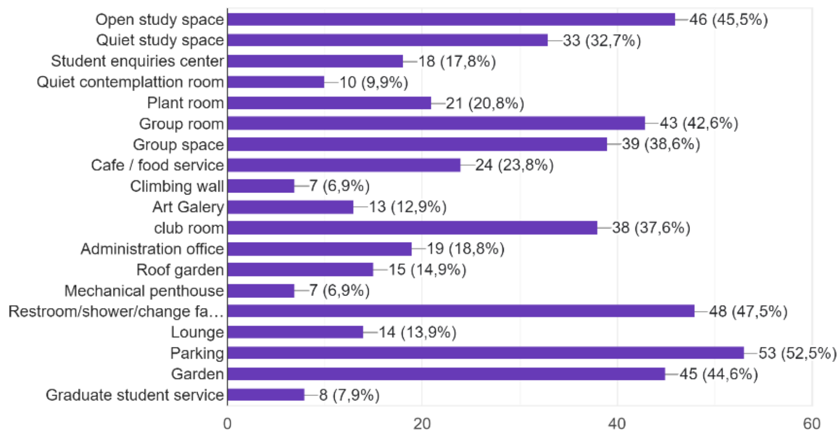


Fig. 01: Facilities Aspect Survey Results Diagram
Source: Author

The design evaluation focuses on calculating the energy efficiency of the existing building to get an overview of energy efficiency. The evaluation includes the resulting efficiency based on the building dimensions, the ratio of openings to walls, and the percentage of available natural ventilation. The software is used to calculate energy efficiency, based on the window-to-wall ratio (WWR) for lighting calculations by considering area and openings.

Fig. 02: Existing of Student Centre Building
Source: Author

The EDGE software is provided by the World Bank and is open for public use. This makes it possible to help design buildings that consider resource efficiency. The software has three components that represent the resources used in buildings; namely energy, water, and materials. However, this research only focuses on energy, especially lighting and ventilation. Building size data, openings and surfaces become parameters for calculating building energy efficiency. Based on the results of evaluations carried out using the EDGE software, the average energy saving of the existing buildings is 25.99%. The percentage meets green building standards based on the EDGE standard. However, the calculation results between the aspects produce a low percentage. The details of the calculation results are shown in the figure below:

Building data Mass 1 (east meeting room)
Gross internal area (m2) : 220.5
Floor above grade : 1
Floor below grade : 0
Floor to floor height (m) : 7.1
Roof area (m2) : 205.6

Mass 1	Energy Saving (%)
Building dimention (m) North : 106 East : 106 South : 106 West :106	- 5.51
WWR (17%)	2.32%
Natural ventilation (59.4%)	19.93%
Total energy saving	**18.83%**

Building data Mass 2 (west meeting room)
Gross internal area (m2) : 220.5
Floor above grade : 1
Floor below grade : 0
Floor to floor height (m) : 7.1
Roof area (m2) : 205.6

Mass 1	Energy Saving (%)
Building dimention (m) North : 106 East : 106 South : 106 West :106	- 5.51
WWR (10.94%)	4.71%
Natural ventilation (59.4%)	19.97%
Total energy saving	**18.83%**

Fig. 03: The evaluations carried out using the EDGE software case building mass 1 (left) and 2 (right)
Source: Author

Building data Mass 3 (north UKM room 1)
Gross internal area (m2) : 97.59
Floor above grade : 1
Floor below grade : 0
Floor to floor height (m) : 6.2
Roof area (m2) : 259.11

Mass 1	Energy Saving (%)
Building dimention (m) North : 20 East : 5 South : 20 West : 5	- 1.62
WWR (20.50%)	1.98%
Natural ventilation (59.4%)	38.07%
Total energy saving	**39.04%**

Building data Mass 4 (south UKM room 1)
Gross internal area (m2) : 115
Floor above grade : 1
Floor below grade : 0
Floor to floor height (m) : 6.2
Roof area (m2) : 280.34

Mass 1	Energy Saving (%)
Building dimention (m) North : 23.65 East : 5 South : 23.65 West : 5	-1.63
WWR (19.79%)	2.25
Natural ventilation (59.4%)	17.07%
Total energy saving	**20.11%**

Fig. 04: The evaluations carried out using the EDGE software case building mass 3 (left) and 4 (right)
Source: Author

Building data Mass 5 (north UKM room 2) Gross internal area (m2) : 97.59 Floor above grade : 1 Floor below grade : 0 Floor to floor height (m) : 6.2 Roof area (m2) : 259.11	
Mass 1	**Energy Saving (%)**
Building dimention (m) North : 20 East : 5 South : 20 West : 5	- 1.62
WWR (20.50%)	1.98%
Natural ventilation (59.4%)	38.07%
Total energy saving	**39.04%**

Building data Mass 6 (south UKM room 2) Gross internal area (m2) : 115 Floor above grade : 1 Floor below grade : 0 Floor to floor height (m) : 6.2 Roof area (m2) : 280.34	
Mass 1	**Energy Saving (%)**
Building dimention (m) North : 23.65 East : 5 South : 23.65 West : 5	-1.63
WWR (19.79%)	2.25
Natural ventilation (59.4%)	17.07%
Total energy saving	**20.11%**

Fig. 05: The evaluations carried out using the EDGE software case building mass 5 (left) and 6 (right)
Source: Author

Natural lighting in the EDGE calculation is shown by the window-to-wall ratio (WWR) energy-saving calculation. The calculation results for the existing Building show that the average energy savings related to WWR are 2.58%. This percentage is relatively low. In Edge User Guide, 2021, savings can be achieved when the window ratio is less than the base case. Buildings with a higher WWR will transmit more heat than buildings with a lower WWR. At the same time, the survey results showed that 51.4% of students were comfortable sitting near the window of Undip's UKM SC Room. While students are comfortable in Undip's UKM SC Room when the window is open as much as 84.1%. If the window is open, it can increase the room temperature. The tendency of users to be near windows encourages the use of air conditioners which can increase electricity consumption.

The existing aperture ratio encourages users not to turn on artificial lighting during the day because there is natural lighting. This fact is shown based on survey results where 79.4% of the students do not turn on the lights during the day. While the color of the lights that tend to be desired by 77.6% of students is neutral. 71% of students chose a natural light intensity of 500 lux. Thus, increasing savings through WWR requires a review of the opening-to-wall ratio of buildings. However, the ratio cannot be reduced considering that students tend to like being near windows and can save on the use of artificial lighting during the day. Therefore, it is necessary to review the glass material used. Where the selected material must be able to isolate the sun's heat. Thus, savings energy can still be achieved even though the ratio of openings is larger or when the window is open.

Analysis of the Findings

From the results of questionnaires distributed to users/students who frequently use this building, interviews with users, and calculations using EDGE software, there are three aspects considered in the development of a new student center, especially those that consider energy efficiency: (1) Physical Aspects of the Building; (2) Ventilation aspects; (3) Lighting aspects. These three aspects are then further analyzed to develop a design development strategy that prioritizes environmental quality.

a. Physical Aspects of the Building

The results of building dimension calculations show an average SC Undip energy saving to be at -2.93%. This figure reflects less savings. However, in the survey which was completed by the 100 respondents, it was shown that 57% of the students found the existing form of the Undip SC building attractive and another 5.6% found it very attractive.

Furthermore, 60.7% of students also felt that the building had reflected the function of the building and another 10.3% said that it was very reflective. 49.5% of students feel that the existing building reflects the characteristics of its users and another 6.5% say it is very reflective.

The survey also revealed that 53.3% of the students felt that the overall appearance of the building was attractive and another 3.7% felt it was very attractive. However, when examined in more detail, the Undip SC facade is not attractive to the students. This is shown through the results of the survey with 52.3% of the respondents feeling the facade of the SC Undip building to be unattractive, while 3.7% felt it was very unattractive. Thus, it is necessary to reassess the shape and the dimensions of the student center building. The basic form of the building can be maintained. However, there is a need for a review regarding the aesthetics of the front facade.

b. Ventilation aspect

Based on the calculation of the EDGE application, the existing Student Center building has an average value of medium savings related to natural ventilation with a percentage of 25.03%. The ventilation system in this building applies a cross-ventilation system with openings opposite to each other. However, based on the results of the questionnaire, as many as 71% of students felt comfortable with the ventilation system. In addition, 96.2% of the respondents including 55.1% of the students felt more comfortable when the windows were opened and the other 41.1% felt very comfortable. Even though the calculation results have exceeded the saving standard, which is 20%, 100% of students with a detailed percentage of 51.4% of respondents feel very comfortable and the other 48.6% feel comfortable when ventilation can be controlled. 100% of respondents consisting of 55.1% felt very comfortable and the other 44.9% felt comfortable when the Air Conditioner is working properly.

Based on the survey results, it can be seen that the use of a mechanical ventilation system provides 3.8% more comfort than a natural ventilation system. However, the presence of natural ventilation can reduce the burden of using air conditioning which can save electricity, thus reducing capital and building maintenance costs. Therefore, the natural ventilation system of an existing building can be maintained or applied as a reference for similar buildings in the future. It's just that efforts are needed to increase comfort in implementing the ventilation strategy.

Comfort in ventilation is related to environmental temperature conditions (thermal). In research by Abdallah (2022), a passive design strategy is described that affects thermal comfort in a university courtyard. The research revealed that a lack of shade and trees can increase temperature thereby reducing thermal comfort. However, it is noted that the condition of the existing building Student Centre is dominated by the pavement. The survey also showed 65.4% of the students with 57% said the availability of green open space (RTH) was not enough, while another 8.4% said it was not enough. These conditions can be an opportunity for improvement of thermal comfort, which is necessary to review the green open spaces of the Student Centre as a passive design strategy to increase thermal comfort.

c. Lighting Aspect

In the aspect of natural lighting, 51.4% of respondents are comfortable near the windows. As many as 84.1% of respondents also said they were comfortable when the window was opened. The intensity of natural light desired by 33.6% of the respondents is when the building faces the North and the East. The availability of natural lighting caused 79.4% of the students not to turn on the lights during the day. This also supports saving electrical energy for room lighting. Furthermore, in terms of artificial lighting, 71% of the students feel comfortable in the UKM room when the artificial lighting intensity reaches 200 lux. Neutral light colors make 77.6% of respondents feel comfortable.

This paper found that conducting a design evaluation of the existing buildings can allows it to be used in a new building design approach by focusing on several aspects that have been previously identified. The results above show that the physical building, lighting, and ventilation are aspects that need to be considered, especially in presenting a design that has energy efficiency and also has a good appearance to support environmental quality. In this paper, the focus is on energy efficiency in the Undip student center which is carried out by calculating lighting and ventilation levels consisting of several elements and finding that the existing buildings have met the minimum green building standards.

The results also show that the existing building design produces 25.99% energy efficiency. This is the basis for the development of new building designs with these minimum standards. Calculations performed using EDGE software make the identification of energy efficiency easier and more accurate. Thus, in developing the next design, the role of EDGE is to evaluate design ideas before finally being developed into a detailed engineering design.

The results show that a design evaluation can be developed not only by focusing on environmental behavior as stated by Zeisel (1981) but by seeing it as a design development program that supports sustainability, especially in detailing architectural elements. Another finding is that building users are not the main aspect, but between use and architecture becomes a balance to realize sustainable architecture. Through the case studies, this paper finds that the position of the physical aspects, lighting, ventilation and facilities are an important part of the development of a student center design that emphasizes energy efficiency.

This paper also shows specifically what is revealed by O'Donovan & O'Sullivan (2023) who point out that good environmental quality can increase the learning concentration of students. On the other hand, this paper also shows a strategy to present a good educational environment through reading the existing environment as a basis for further design development. In the architectural discourse, an educational environment is seen more as a regional function. This paper shows that the evaluation of existing buildings in educational environments can be carried out using methods that involve students as users and also use software, especially energy efficiency. This is an effort to read the existing building as a context, for a method of design development.

Conclusion

Presenting a quality environment that supports students to carry out activities is one of the efforts to generate student creativity in an educational environment. The learning concentration of students can be helped by the presence of an environment that has good acoustic quality, thermal comfort, air quality and visual quality. One of the efforts that can be made is to present buildings by considering energy efficiency. This can produce a healthy and quality environment, especially in an educational environment. This paper is a search for a form of educational environment that supports a good environmental quality based on building design. In particular, this paper carries out a design evaluation of the student center building, as a basis for further design development of the student center building.

This paper shows that in the development of a new student center, it is necessary to consider the following.

(1) Reviewing the shape of the building, the ratio of openings, and the building's ventilation system in order to increase the ability to save energy.
(2) Additional facilities such as open study spaces, quiet study spaces, cafes/food services, roof gardens, and open spaces.
(3) Revisiting the aesthetics of the student center building or facilities based on the physical opening.

It is argued that these findings could become inputs for Diponegoro University in developing the Undip student center building and supporting the Undip strategic plan related to the fulfillment of campus facilities and the realization of a green and sustainable environment.

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