International Proceeding
Universitas Tulungagung
2025

UNDERSTANDING SUSTAINABLE DESIGN INNOVATION AND ENTREPRENEURSHIP INSPIRATION FOR STUDENTS IN THE BUILDING INFORMATION MODELING AND DESIGN MAJOR

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Abstract

This study aims to identify and analyze the level of understanding of sustainable design innovation and entrepreneurship inspiration among students of Vocational High Schools (SMK) majoring in Building Information Modeling and Design (BIM Design/DPIB). In addition, this study also aims to explore alternative solutions to improve the effectiveness of students' understanding of sustainable design innovation and entrepreneurship inspiration. This study uses a quantitative method by conducting a survey to measure the level of students' understanding of sustainable design innovation and entrepreneurship inspiration. The data collection technique in this study used a pre-test and post-test with a total of 156 respondents from grade 11 DPIB SMKN 1 Donorojo and SMKN 1 Pacitan. The level of understanding of students of SMKN 1 Donorojo and SMKN 1 Pacitan regarding sustainable design innovation and entrepreneurship inspiration shows significant variations based on several factors, includinglearning infrastructure support factors, learning environment and applied teaching approaches. This research is significant because it provides in-depth insights into the understanding of sustainable design innovation and entrepreneurship inspiration for grade 11 DPIB students of SMKN 1 Donorojo and SMKN 1 Pacitan. The results of this study can provide a better understanding for DPIB major students who need an in-depth understanding of sustainable design as preparation for entering the world of work and entrepreneurship. This can be a valuable guide for teachers to improve the quality of sustainable design-based learning and can inspire students to become entrepreneurs relevant to the DPIB major.

Keywords: *Green Building, Sustainable Design Innovation, Entrepreneurship Inspiration, Environmental Awareness, Vocational Education.*

INTRODUCTION

Sustainability is the foundation of responsible management and offers a way to preserve our planet for future generations. As defined by the United Nations Brundtland Commission, sustainable development involves "meeting the needs of the present without compromising the ability of future generations to meet their own needs" (Our Common Future, 1987). Growing global awareness of climate change and environmental degradation has made green buildings a primary choice. As a student majoring in Building Information Modeling and Design, you certainly have access to understand this as an effort to innovate sustainable design.

Green building design and energy efficiency have become important considerations in contemporary construction practices, driven by increasing global awareness of environmental degradation and energy consumption.(Aniekan, et al., 2024). Sustainable green buildings can reduce negative impacts on the environment and provide positive benefits by creating a healthy environment for their occupants. Sustainable design innovation has become a major focus in modern construction, especially with the increasing attention to global climate change issues, resource efficiency, and the impact of development on the environment. Understanding sustainable design encourages environmental awareness among students. Thus, students will not only become competent professionals but also individuals who are responsible for their social and ecological impacts. This is in line with the global commitment to the Sustainable Development Goals (SDGs), specifically point 11 on Sustainable Cities and Communities and point 13 on Action on Climate Change.

According to the United Nations Environment Programme (UNEP), the building sector is responsible for approximately 39% of global CO2 emissions. The latest technology applied in green building-based learning can reduce the carbon footprint on earth and increase energy efficiency. As a sustainable design innovation, green buildings also offer operational cost savings through reduced energy and water consumption, and certified buildings such as Leadership in Energy and Environmental Design (LEED) or Green Building Council Indonesia (GBCI) have a higher market value. Technological advances such as the Internet of Things (IoT), artificial intelligence (AI), and innovative materials will be increasingly integrated into the design and operation of green buildings (Indonesia Environment & Energy Center, 2024). Therefore, this information can motivate students to be able to incorporate sustainability into the building designs they create.

A deep understanding of sustainable design will give students a competitive edge in the workplace. Furthermore, today's workforce is in dire need of experts capable of creating innovative solutions to address sustainability challenges in the construction sector. Students will also be better equipped to develop their creativity and produce inspiring designs, while also generating inspiration for environmentally friendly business ventures. The combination of design and sustainability presents a dynamic arena for eco-innovative practices, particularly in the field of construction design.(Joshua, Nwakamma, Kehinde, Emmanuel, & Irunna, 2024). This study provides an understanding of the importance of sustainable design innovation, equipping students with the necessary skills in the context of sustainable environmental awareness and inspiring student efforts in the field of green construction. This study examines the integration of sustainable design, emphasizing the importance of minimizing the ecological footprint of buildings.

LITERATURE REVIEW

Vocational Education Department of Building Information Modeling and Design (DPIB)

Vocational school programs are tailored to the needs of the workforce. Vocational school programs are also tailored to the demands of society and the job market. Building Information Modeling and Design (DPIB) program focuses on building planning, construction, repair, and other areas. Learning activities in this program include drawing house, building, and apartment designs, calculating building costs, carrying out construction, and maintaining

building structures. Several subjects in the DPIB program include technical drawing, engineering mechanics, fundamentals of building construction, software applications, interior design, land surveying techniques, and more.

Building Information Modeling and Design is a program of expertise that studies the planning, implementation, and improvement of building structures starting from land measurement, pre-construction planning, construction calculations to the presentation of the final design accompanied by the results of the calculation of the cost budget plan, work plan, and needs (RKS) for the implementation of the work. Building Information Modeling and Design

plays a role in contributing to the arrangement of city/district land, because information from city/district spatial plans helps the continuity of building planning to reduce design uncertainty, find problems and solutions, improve safety, and simulate the construction process and analyze the impact of potential problems that may arise.

Entrepreneurship Inspiration

Entrepreneurship is the process of doing or creating something new in a creative and innovative way. According to Wikipedia, entrepreneurship is the process of developing, identifying, and realizing a vision and mission in life. The definition of entrepreneurship according to experts is as follows:

1. Ahmad Sanusi (1994)
   Entrepreneurship is a value that is manifested in behavior that is used as a resource, driver, goal, strategy, tips, process and entrepreneurship results.
2. Drs. Joko Untoro
   Entrepreneurship is the courage to make efforts to fulfill life's needs carried out by a person, based on their abilities by utilizing all their potential to produce something that is beneficial for themselves and others.
3. Drucker (1959)
   Entrepreneurship is the ability to create something new and different.
4. J. Leach Ronald Melicher
   According to J. Leach Ronald Melicher in his book entitled "Eddy Soeryanto Soegoto," entrepreneurship is a creative effort built on innovation to produce something new, add value, provide benefits, create jobs, and produce results that benefit others. Entrepreneurship is the process of transforming ideas into commercial opportunities and creating value (price).
5. Decree of the Minister of Cooperatives and Small Business Development Number 961/KEP/M/XI/1995.
   Entrepreneurship is the spirit, attitude, behavior and ability of a person in handling a business or activity that leads to efforts to discover, create and apply new working methods, technologies and products by increasing efficiency in order to provide better service and/or obtain greater profits.
6. Siswanto Sudomo (1989)

According to Siswanto Sudomo (1989), entrepreneurship is everything that is important in an entrepreneur, namely a person who has the nature of working hard and being willing to make sacrifices, focusing all his energy and daring to take risks to realize his ideas.

7. Zimmerer (1996)
   Entrepreneurship is the process of applying creativity and innovation in solving problems and finding opportunities to improve lives.

Inspiration is often considered a crucial element in the creative process. Inspiration provides the impetus to think outside the box and discover new solutions or ideas that have never existed before. Amabile (1983) explains that creativity involves the generation of new ideas, and inspiration is one of the main triggers that helps individuals tap into their creative potential. Some experts argue that inspiration is the beginning of the creative process, which then develops through critical thinking and hard work to produce something innovative and useful. Boden (1990) states that creativity emerges from a combination of initial inspiration and in-depth exploration of a problem or challenge.

In the context of entrepreneurship, inspiration plays a crucial role in driving someone to start and grow a business. Kuratko (2016) explains that successful entrepreneurs often get their business ideas from personal experiences, observing market needs, or interacting with mentors and professional relationships. De Jong and Wennekers (2008) state that inspiration is a crucial factor in business innovation. Inspiration encourages entrepreneurs to think beyond conventional boundaries and see new opportunities that might otherwise be invisible to others.

Environmental Concern

Environmental concern is an interest in the environment that is influenced by feelings (Dagher and Itani 2012). Environmental issues that are increasingly prevalent in print and electronic media include issues regarding waste, the biosphere, environmental responsibility, health education, and even energy scarcity, which makes consumers feel concerned about environmental issues that occur. According to Mostafa (2007), environmental concern is an attribute or affective feeling that can represent feelings of worry, enthusiasm, or dislike for the environment.

Concern for the environment can also be interpreted as human emotional involvement in environmental issues (Lee, 2008 in Dagher and Itani 2012) On the other hand, environmental issues have three factors, namely concern for the environmental layers of living creatures' habitats consisting of the lithosphere, hydrosphere, and atmosphere. Concern for the environment includes three interrelated issues: concern for the biosphere, concern for fellow humans and concern for oneself (Schultz, 2000 in Dagher and Itani 2012). According to Biology, the definition of the biosphere is the layer of the earth in which life on earth exists. According to Geography, the definition of the layer where living creatures live or the entire living space occupied by organisms. Etymologically, the term biosphere comes from two words, namely bio which means living things and sphere which means layer. So the biosphere is a layer of life (flora and fauna).

According to the Republic of Indonesia Law No. 4 of 1982, concerning the basic provisions of environmental management and the Republic of Indonesia Law No. 32 of 2009, concerning environmental management that: the environment is a unity of space with all

objects, power, conditions, and living creatures, including humans and their behavior, which affect nature itself, the continuity of life, and the welfare of humans and other living creatures. Environmental management can be interpreted as a conscious effort to maintain or improve the quality of the environment so that basic needs can be met as well as possible. Environmental awareness is an awareness to direct the attitudes and understanding of society towards the importance of a clean, healthy environment, and so on. Dagher and Itani, 2012 stated that a person's concern for the environment can be seen from the following things:

a. Concern for environmental issues
b. Concern for environmental issues
c. Concerns about environmental quality
d. Concern for improving environmental quality

Green Building

Green Building is the practice of creating or making structures using processes that are environmentally and resource-responsible throughout the building's life cycle, from placement to design, construction, operation, maintenance, renovation, and deconstruction. Green Building is also known as a high-performance or sustainable building (US EPA, 2009). Green Building, or often also called green building, is a plan in designing, constructing, managing, and maintaining a building that has the goal of not only maintaining the health of building occupants, but also increasing the ability, creativity of building occupants, using natural materials appropriately, and can reduce the negative impact of buildings on the environment. So in fact, the Green Building concept really considers the condition of the surrounding environment, including in its construction aspects (Batuwangala in Gupta, 2013).

Sustainable design requires the integration of multiple disciplines, from planning and implementation to operation and maintenance, through to demolition. The greater the collaboration during the design phase, the greater the opportunity to improve a building's sustainability. Buildings designed with sustainable principles are known as green buildings.

Sustainable Design Innovation

Sustainable design is a design that throughout the process, from the extraction of natural resources to recycling, uses methods that do not harm the environment or human health, so that human life and nature on earth can continue to survive (Febriany et al., 2013). Green architecture is a building that is designed, constructed, and operated with minimal impact on the environment, or even has a positive impact on the environment, while improving the health, welfare, and quality of life of its occupants. According to the Green Building Council Indonesia, a green building is a building that in its planning, construction, operation, and maintenance pays attention to various aspects of protecting, saving, reducing the use of natural resources, maintaining the quality of both the building itself and indoor air quality, and paying attention to the health of its occupants, all of which are based on the principles of sustainable development. According to Amoros Rappoport in his book History and Precedent in Environmental Design, what is expected from sustainable design is to completely eliminate negative impacts on the environment through a design approach. The embodiment of sustainable design includes an attitude of not using non-renewable resources, minimizing

impacts on the environment, and trying to reunite humans with their natural environment. Although there are various standards and understandings, some generally accepted basic principles of sustainable design include the following aspects:

a. Low impact materials: using non-toxic materials and produced in an environmentally friendly manner.
b. Energy efficiency: using or making products that require less energy.
c. Quality and durability: products that function well (have a long service life) mean less maintenance or replacement.
d. Reuse and recycle: product design should consider continued use after the end of its useful life (after-life).
e. Renewal: the materials are locally sourced, produced from renewable resources, and (where possible) compostable.
f. Healthy: the product is not harmful to users/occupants and the surrounding environment, and can even support general health aspects.

Innovative Sustainable Design is a concept that integrates innovation in the design process with sustainability principles. Sustainable design seeks to produce products, services, and environments that minimize negative impacts on the environment and natural resources, while considering long-term economic and social aspects (Bhamra, 2018). Innovation in this context involves the development of new ideas, techniques, and solutions that significantly reduce environmental impact and improve quality of life.

RESEARCH METHODS

This study used quantitative methods as the primary approach to explore and analyze students' understanding of sustainable design innovation and entrepreneurship inspiration. The quantitative approach was chosen because of its ability to provide objective, measurable, and generalizable results. This method aims to collect numerical data, test formulated hypotheses, and explain phenomena based on statistical analysis.

In this study, the data collection instrument used was a test sheet (pre-test and post-test) designed to ensure the accuracy and consistency of respondents' answers. The respondents involved were 11th grade students majoring in Building Information Modeling and Design (DPIB) at SMK Negeri 1 Donorojo and SMK Negeri 1 Pacitan, East Java, and the data analysis techniques used descriptive statistics. The research stage will be divided into 3 activities, pre-test, material intervention, and post-test :

1) A pre-test is the initial stage used to measure participants' abilities, knowledge, or skills before the intervention. The goal is to determine the participants' initial condition and obtain baseline data that will be compared with the post-test results. The pre-test was administered to both groups to measure the level of sustainable design innovation and initial entrepreneurship inspiration.
2) Material Intervention is the stage of providing treatment in the form of materials, training, or learning methods to research participants. Material intervention aims to provide treatment that is expected to improve participants' abilities in accordance with the research objectives. In this study, material intervention was conducted on sustainable design innovation and entrepreneurship inspiration.

3) The post-test is the final stage to measure changes in participants' abilities, knowledge, or skills after the intervention. After the intervention, re-measurements were conducted on sustainable design innovation and entrepreneurship inspiration in both groups. A comparison of pretest and posttest results will be used to determine the effect of the intervention. The purpose of the post-test is to assess the effectiveness of the intervention and to compare pretest and post-test results to determine the changes that have occurred. The test or evaluation conducted must be the same or equivalent to the pre-test to ensure valid comparisons. Post-test results are used as the final data for analysis. After completing all three stages, data from the pre-test and post-test are analyzed to test for significant differences in ability improvement after the intervention and to determine the intervention's effectiveness through statistical tests.

The data analysis technique used is ANOVA (Analysis of Variance).ANOVA is a multivariate analysis technique that distinguishes the means of more than two data groups by comparing their variances. Analysis of variance falls under the category of parametric statistics. ANOVA is also a form of statistical hypothesis testing in which researchers draw conclusions based on data or groups of inferential statistics. ANOVA is a statistical method used to analyze the comparison of the means of two or more independent data groups. The main purpose of ANOVA is to find significant differences that appear between the means of these groups.

RESULTS AND DISCUSSION

In essence, the Building Information Modeling and Design major focuses on the basic competencies that workers in the field of building design and information modeling must possess in accordance with developments in the world of work. In addition, students are given an understanding of entrepreneurship processes, developments in technology applications and global issues, entrepreneurial profiles, job profiles, entrepreneurship opportunities, and jobs/professions. Students who understand global issues such as climate change or environmental damage will be more sensitive to the importance of environmentally friendly design innovation. This encourages students to create entrepreneurship inspiration based on solutions to these issues, such as creating products that support sustainability. The elements and descriptions of the elements of the Building Information Modeling and Design Basics subject are as follows:

Table 1. Elements and Element Descriptions

No.	Element	Information
1.	Technological developments and global issues in building information modelling and design	Covers technological developments and global issues related to green buildings and sustainable buildings which are used as a basis for describing building construction.
2.	Professions and entrepreneurship (job profiles and technopreneurship) and entrepreneurship opportunities in the field of building modeling and information design	Covers the scope of professions and entrepreneurship opportunities as entrepreneurs (technopreneurs) and/or consultants in the field of planning, implementation, building supervision, and can also continue higher education.

No.	Element	Information
3.	Basic techniques in Building Information Modeling and Design work	Covers the introduction and basic practices related to modeling design and building information work, including drawing equipment, measurement equipment, operation and maintenance of measurement equipment, and analysis of measurement work results.
4.	*Building Information Modeling* (BIM)	Covers the understanding, functions and examples of BIM so that students can imagine virtual construction before physical construction is built, to reduce uncertainty, increase safety, solve problems, as well as simulate and analyze. potential impacts that may arise.
5.	Specifications and Characteristics of Green Material-Based Building Materials and Construction Work	Covers the specifications and characteristics of green-based building materials and various types of construction work that underlie building construction drawings, by raising global issues related to green buildings and sustainable buildings that are used as the basis for construction drawings.

Learning Outcomes: At the end of Phase E, students gain an overview of their chosen program of expertise, fostering enthusiasm and vision for planning and implementing learning activities. Furthermore, students are able to draw basic engineering drawings, understand BIM, and carry out basic building construction and land surveying, applying K3LH process procedures. Learning Outcomes for each element are as follows.

Table 2. Learning Outcomes

No.	Indicator	Learning Outcomes
1.	Technological developments and issues global in building information modelling and design	Students are able to understand technological developments and global issues related to green buildings and sustainable buildings which are used as a basis for depicting building construction.
2.	Professions and entrepreneurship (job profiles and technopreneurship) and entrepreneurship opportunities in the field of building information modelling and design	Students are able to understand professions and entrepreneurship (job profiles and technopreneurship) as well as entrepreneurship opportunities in the field of building modeling and information design, by applying real project-based learning as a simulation of entrepreneurial projects.
3	Basic techniques in design work building modeling and information	Students are able to understand the basic techniques of modeling design work and building information through introduction and basic practice related to modeling design work and building information, applicable standards and regulations related to buildings.
4.	*Building Information Modeling* (BIM)	Students are able to understand BIM so that students can imagine virtual construction before physical construction is built, to reduce uncertainty,

No.	Indicator	Learning Outcomes
		increase safety, solve problems, and simulate and analyze potential impacts that may arise.
5.	Specifications and Characteristics of Green Material-Based Building Materials and Construction Work	Students are able to understand the specifications and characteristics of green material-based building materials and various types of construction work that underlie building construction drawings, by raising global issues related to green buildings and sustainable buildings that are used as the basis for construction drawings.

Overall, these learning outcomes equip students with skills that are not only technical but also related to environmental awareness and entrepreneurship opportunities in the field of building information modeling and design. Project-based learning and an introduction to advanced technologies like BIM will help students better prepare for the challenges of industry and entrepreneurship.

The test scores of 156 respondents showed varying results. Using a descriptive test with the results in Table 3. The results of the descriptive test show that the average score of SMKN 1 Pacitan (83.49) is higher than the average score of SMKN 1 Donorojo (79.93). The range of scores (minimum-maximum) in both classes is relatively similar, but SMKN 1 Pacitan has a smaller variation (lower standard deviation, 4.938 compared to 6.390). SMKN 1 Pacitan has a higher average score than SMKN 1 Donorojo, indicating better overall performance. The variation in scores at SMKN 1 Donorojo is greater, meaning there is more difference between students in that class than at SMKN 1 Pacitan. The confidence interval shows that the average scores of each class differ consistently, so this difference is likely significant.

Table 3. Descriptive Test Results

	N	Mean	Standard Deviation	Minimum	Maximum
SMKN 1 Donorojo	78	79.93	6,390	68	94
SMKN 1 Pacitan	78	83.49	4,938	70	96

The pretest results for SMKN 1 Donorojo indicate that understanding of innovation and creativity in sustainable design is still lacking. This is because at SMKN 1 Donorojo, learning related to green buildings and entrepreneurship is still basic. Meanwhile, the pretest results for SMKN 1 Pacitan indicate a higher level of understanding. This is because at SMKN 1 Pacitan, learning related to green buildings and entrepreneurship has begun to be implemented in the classroom. SMKN 1 Pacitan, which is located in a more developed urban area, supports the formation of a creative entrepreneurial ecosystem. Students have more access to design exhibitions, innovation competitions, and entrepreneurship opportunities in the construction and interior sectors. SMKN 1 Pacitan has more adequate learning facilities and infrastructure to support technology-based design practices. This plays a crucial role in generating entrepreneurship inspiration rooted in environmentally friendly design principles.

In contrast, SMKN 1 Donorojo still faces limitations in technological facilities, digital learning resources, and access to collaboration with industry. Learning at this school is still

dominated by basic theory and practice, resulting in a less than optimal understanding of the integration of sustainability, innovation, and entrepreneurship.

Thus, it can be concluded that the high level of understanding among students at SMKN 1 Pacitan is due to a combination of supporting learning infrastructure and a learning environment that is more open to innovation. These factors make them better able to understand and apply the concept of sustainable design innovation and connect it to entrepreneurial potential in the design and construction fields.

Based on the ANOVA test results data, the following values can be identified:

Table 4. ANOVA Test Results

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1479.111	1	1479.111	45,360	.000
Within Groups	15195.3	154	32,608		
		155			

Between Groups in the table above shows the variability of data between groups (mean difference between groups), Sum of Squares (SS): 1479.111 (total variation between groups), df (degrees of freedom): 1 (number of groups - 1), and Mean Square (MS): 1479.111 (calculated by dividing SS between groups by df). Within Groups shows the variability of data within groups (variation within each group), Sum of Squares (SS): 15195.368 (total variation within groups), df: 154 (total number of data - number of groups), and Mean Square (MS): 32.608 (calculated by dividing SS within groups by df). F (F value) is calculated using the formula:

$$F = \frac{Mean\ Square\ Between\ Groups}{Mean\ Square\ Within\ Groups} = \frac{1479{,}111}{32{,}608} = 45{,}360$$

The F value indicates how large the mean difference between groups is compared to the variation within groups. The significance value (p-value) shows a value of 0.000 which indicates that the mean difference between groups is statistically significant. Interpretation of the results shows that the F-value = 45.360 is a fairly large statistical F value, indicating that the variation between groups is significant compared to the variation within groups. A significance value showing a value of 0.000 means that there is a statistically significant difference between the mean scores in the compared groups because $p < 0.05$. The mean difference between groups in this analysis is statistically significant. The results indicate that the groups have significantly different scores, and the null hypothesis (that there is no difference between groups) can be rejected.

Problems in DPIB Students' Understanding of Sustainable Design Innovation and Entrepreneurship Inspiration

In studying sustainable design innovation and entrepreneurship inspiration, Building Information Modeling and Design (DPIB) students in Phase E (advanced evaluation and exploration) often encounter several challenges that affect their understanding and practical application. These challenges can be categorized into cognitive, practical, and supporting environmental aspects.

Cognitive problems stem from students' lack of understanding of theoretical concepts, making it difficult for them to grasp abstract concepts about sustainability in design, such as calculating energy efficiency or the environmental impact of building materials. This is often due to a lack of mastery of basic materials related to environmentally friendly technologies. Furthermore, students often lack sufficient knowledge of how innovations in sustainable design can be translated into entrepreneurship opportunities. Entrepreneurial inspiration requires deeper insight into entrepreneurship and marketing strategies, which are not always integrated into design materials.

Practical issues such as lack of access to modern technology impact the understanding of sustainable design innovations, which often require technologies like Building Information Modeling (BIM) or other 3D design software. However, not all schools have adequate technological infrastructure to support learning about sustainable design. Another challenge is the difficulty of integrating sustainability with local design, which often hinders students from adapting sustainable design principles to local contexts, such as adapting environmentally friendly materials to the availability of resources in rural areas.

The supportive environment also poses a challenge, as students require hands-on experience through internships or industry collaborations. However, not all regions have industries actively practicing sustainable design, leaving students with limited practical insights. The curriculum's alignment with global trends sometimes doesn't reflect the latest developments in sustainable innovation, preventing students from fully understanding the relevance of this material to the workplace.

DPIB Students' Understanding of Sustainable Design Innovation Solutions and Entrepreneurship Inspiration

In phase E (evaluation and further exploration), students majoring in Building Information Modeling and Design(BID Design) are expected to understand the concept of sustainable design innovation and connect it to entrepreneurship ideas relevant to the construction and design fields. This understanding encompasses conceptual, applicative, and exploratory aspects related to the challenges and opportunities in creating environmentally friendly, efficient, and economically valuable building designs.

DPIB students' cognitive understanding of sustainable design innovation and entrepreneurship inspiration in phase E can be enhanced through various learning approaches and supporting strategies. This solution is designed to overcome theoretical understanding barriers and enhance students' critical and innovative thinking skills.

1. Integrated Learning Approach

   Integrating project-based learning (PjBL) with the theme of sustainable design innovation can help students connect theory with practice. In this context, students are given real-life projects, such as designing an energy-efficient building using environmentally friendly materials, so they can more easily understand sustainability principles in a practical way. This method is effective because it actively engages students in the learning process.

2. Strengthening Concepts Through Digital Simulations

The use of software such as Building Information Modeling (BIM) can help students visually understand sustainable design simulations. These simulations cover energy efficiency, material management, and the environmental impact of the designs. This technology allows students to see the results of their design innovations directly, reinforcing both visual and practical learning.

3. Thematic Workshops and Training

Hosting workshops focused on sustainable design topics, involving practitioners and experts in the field, can enrich students' knowledge. For example, bringing in experienced architects or designers working on green building projects to share insights on the real-world application of sustainability principles.

4. Integration of Entrepreneurship Education

To foster entrepreneurial inspiration, sustainable design innovation materials should be linked to entrepreneurship opportunities. Students should be equipped with entrepreneurial insights, such as how to identify local market needs for sustainable design and create appropriate products or services. This material can be delivered through case studies or entrepreneurship simulations.

5. Development of Modular Learning Materials

Developing digital learning modules that include real-world examples of sustainable design applications can help students learn independently. These modules can include interactive videos, step-by-step tutorials, and quizzes to assess student understanding.

These approaches not only enhance students' understanding of sustainable design innovation materials but also develop critical, creative, and adaptive thinking skills. Furthermore, these solutions equip students with relevant entrepreneurial skills, better preparing them to face global challenges in design and construction.

Therefore, DPIB students in phase E often face practical challenges in understanding and applying sustainable design innovation materials and entrepreneurship inspiration. These challenges include limited access to technology, a lack of practical facilities, and minimal industry involvement. The following solutions can be implemented to address these challenges:

1. Provision of Adequate Technological Infrastructure

Understanding sustainable design innovation requires technology such as 3D design software (e.g., AutoCAD, BIM) and sustainability simulation tools. Schools can partner with technology companies to obtain free or affordable educational software licenses. Additionally, providing design labs that support eco-friendly building simulations can help students understand sustainability principles in a practical way.

2. Collaboration with Industry for Training and Projects

Engaging industry as a partner in hands-on training provides students with valuable experience. For example, students can intern at a company that emphasizes sustainable design principles or work on collaborative projects to design environmentally friendly products. This approach provides hands-on understanding of real-world applications.

3. Optimization of Local Resources

To overcome the limitations of modern materials, students can be guided to utilize sustainable local resources, such as bamboo or engineered wood. This approach not

only supports sustainable design innovation but also instills environmental values and local business potential.

4. Teacher Training Program

   Teachers play a crucial role in addressing practical problems. On going training for DPIB teachers can help students update their knowledge of current technologies, sustainable design trends, and entrepreneurial practices. Skilled teachers can guide students more effectively.

5. Design Exhibitions and Competitions

   Hosting a local sustainable design exhibition or competition can be a creative way to strengthen students' practical skills. By showcasing their work to the public and industry, students receive constructive feedback and build confidence in implementing design innovations.

   Implementing this solution not only enhances DPIB students' practical skills but also equips them with relevant skills to compete in the job market. Students will be better prepared to face industry challenges that increasingly prioritize sustainability, while also being inspired to develop business ideas based on design innovations that positively impact society and the environment.

Finally, a supportive environment significantly influences DPIB students' success in understanding sustainable design innovation materials and developing entrepreneurial inspiration. Challenges within the supportive environment can include a lack of family involvement, limited school facilities, and minimal collaboration with external parties. Here are some solutions to address these challenges:

1. Improving Learning Facilities

   A supportive physical environment, such as a design laboratory equipped with the latest technology, is a fundamental requirement. Providing simulation tools, BIM software, and practice-based teaching materials can help students understand sustainable design innovation more effectively. Schools can also establish entrepreneurship practice spaces that allow students to create product prototypes and simulate business ventures.

2. Parental and Community Support

   Active parental involvement in their children's education can strengthen a supportive environment at home. Parents can be encouraged to participate in school projects, such as exhibitions or design competitions, creating synergy between formal and informal learning. Furthermore, local community involvement in supporting school programs, such as providing resources or internship opportunities, will strengthen the educational ecosystem.

3. Collaboration with Local Industries and MSMEs

   A supportive environment can be strengthened through partnerships with local MSMEs and creative industries. This collaboration can take the form of training, internships, or locally-needed projects relevant to sustainable design. Direct involvement with the workplace provides students with real-world experience, enhancing the relevance of the material learned to real-world challenges.

4. Strengthening School Policies

   School policies that support learning about sustainable design innovation are also important. Schools can establish mandatory sustainability-based programs, such as community-based projects or an introduction to green entrepreneurship. These policies create a culture of sustainability within the school and encourage students to think creatively to find innovative solutions.

5. Access to Teacher Training

   Teachers are a key element in creating a supportive environment. Ongoing training focused on teaching sustainable design innovation and entrepreneurship can help teachers deliver relevant and engaging content. Competent teachers will be able to inspire students to apply their knowledge in practical ways.

   These solutions will collectively create a supportive and holistic environment for DPIB students. This supportive environment allows students to develop cognitive, practical, and entrepreneurial skills, making them better prepared to face global challenges in sustainable design and construction.

CONCLUSION

The level of understanding of grade XI DPIB students at SMKN 1 Donorojo and SMKN 1 Pacitan regarding the material on sustainable design innovation and entrepreneurship inspiration shows significant variations based on several factors, including learning infrastructure support factors, the learning environment, and the applied teaching approach. The following is a conclusion from the comparison of student understanding at the two schools. Students at SMKN 1 Donorojo are generally at the basic understanding stage in recognizing the concept of sustainable design innovation. Students tend to have a more theoretical and conceptual understanding. This is because learning at SMKN 1 Donorojo places more emphasis on introducing the basic principles of sustainability in design and an initial understanding of entrepreneurship. Although students are enthusiastic, their limited practical experience is a major challenge in understanding the application of these concepts in the real world. Meanwhile, students at SMKN 1 Pacitan usually show a deeper understanding, especially more applied learning through projects, creative innovation, simulations, or collaboration with industry. At this level, students begin to understand the relationship between sustainable design innovation and entrepreneurship opportunities, which is strengthened through a project-based approach and entrepreneurship training.

This success is highly dependent on the quality of the curriculum, teacher support, and engagement in hands-on activities. Meanwhile, students at SMKN 1 Donorojo require a more interactive approach to build a solid foundation of knowledge. The level of understanding of DPIB students at SMKN 1 Donorojo and SMKN 1 Pacitan on sustainable design innovation and entrepreneurship inspiration material develops gradually, with the main differences being the learning environment, learning facilities, and application capabilities. A well-structured educational program, accompanied by the support of facilities and a supportive learning environment, is crucial to improving students' understanding at the same level but facing different challenges, so that students can become creative and competitive innovators in the future.

From the analysis results, it can be concluded that the null hypothesis (H0) stating "there is no difference in mean scores between groups" can be rejected. This result indicates a significant difference between the mean scores of the analyzed groups. This significant difference in mean scores provides evidence that the tested variables influence the group scores. Therefore, different actions or policies in these groups can be considered relevant to influencing the measured outcomes or achievements.

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