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BUILDING SUSTAINABLE ENTREPRENEURSHIP WITH A SCIENCE-BASED GREEN ENTREPRENEURSHIP LEARNING MODEL AND SUSTAINABLE DEVELOPMENT GOALS IN ISLAMIC BOARDING SCHOOLS

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ABSTRACT

The purpose of this research is to examine the implementation process of the Green Entrepreneurship project model to build sustainable entrepreneurship grounded in science and the SDGs in Islamic boarding schools. The qualitative approach of the grounded theory method: 1) Determining the design; 2) Formulating the problem; 3) Access to the research setting; 4) Data collection procedures; 5) Coding process; 6) Selective coding; 7. Validation of the theory. Data collection techniques: interviews, observations, and documentation of informants. Data analysis techniques from the researcher's entry into the field through the end of the research: displaying, reducing, analyzing, and concluding data. Data validity test: triangulation of credibility tests, member checks, and audit trails with VOSviewer novelty analysis. The results of the study show a three-dimensional transformation of Islamic boarding school entrepreneurship, namely Islamic spirituality as the foundation of values of concern for God's creation based on environmentally friendly businesses, integration of science not only spiritual values, but using scientific methods, technology, and innovative, efficient, sustainable business research, and innovation technology, as well as ecological awareness as a sustainable direction so that the theory is formed "Theoretical novelty of developing a green entrepreneurship learning model based on science, STEAM, SDGs, and Islamic boarding school spirituality, methodological novelty of transdisciplinary learning strategies with Islamic boarding school education policies and green entrepreneurship curriculum", Islamic boarding school efforts to foster environmentally friendly, social economic independence and sustainable development, not only limited to formal Madrasah education, but the entire educational and spiritual ecosystem that lives in it.

Keywords: green entrepreneurship learning model; islamic boarding school; SDGs; STEAM; grounded theory

INTRODUCTION

As educational institutions grounded in spiritual values, Islamic boarding schools play a strategic role in shaping a generation that not only possesses noble character but also life skills relevant to the challenges of the times. In the current era of globalization and environmental crisis, Islamic boarding schools must adapt to the 21st-century educational paradigm that emphasizes creativity, innovation, collaboration, and digital literacy. One urgent need is to deve-

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lop sustainable entrepreneurship that can address environmental issues while improving community welfare. Students living in Islamic boarding schools are agents of change, cultivating environmentally friendly lifestyle habits and developing character. Education significantly influences and impacts student character. Future-oriented education is expected to develop and enhance knowledge and skills, producing agents of change, creative individuals, experienced individuals, critical thinkers, innovative and visionary individuals, communicative individuals, individuals with an entrepreneurial spirit, individuals with curiosity, and individuals developing extensive networks (Meishanti et al., 2023).

Pesantren, as an agent of change, is not only a religious educational institution but also a center for economic and social empowerment. The students are encouraged to become entrepreneurs who are not only economically independent but also care about the environment and society, in line with the SDGs, a movement that supports sustainable development goals by instilling sustainable values in business practices. Utilizing local wisdom as a learning resource allows students to build new knowledge in the context of their surrounding environment, so that science concepts no longer feel abstract (Yolida et al., 2021). The importance of scientific issues in learning, especially science, is to provide meaningful learning situations for students so that they can apply their scientific knowledge in a social environment (Ilmi & Erman, 2019). Local wisdom in the community can be a valuable resource for making science learning more meaningful, as local wisdom-based learning involvesestructuring local knowledge and linking it to scientific concepts (Hamdani M et al., 2019). Science education requires students to learn abstract and complex concepts that are difficult for them to understand and apply in real-world situations (Potkonjak et al., 2016; McColgan et al., 2017; Lai, 2023; Siming & Abraha, 2023; Kusumadani et al. 2024). Students' misunderstandings about health concepts and local wisdom can become sustainability issues when they apply these misconceptions in their daily lives. One way to address this issue is through appropriate education (Gani et al., 2024)

The urgency of this research is high because: 1) It addresses global and local challenges related to facing complex environmental, social, and economic crises, aiming to identify contextual solutions relevant to SDG 12 (Sustainable Consumption and Production) and green entrepreneurship practices; 2) It supports educational transformation, as the current curriculum has not fully integrated the values of sustainability and green entrepreneurship. This research is important for designing a transformative learning model, based on STEAM (Delgado-Rodríguez et al., 2023) and spiritual values; 3) It encourages ecological literacy and social innovation, where the younger generation needs to be equipped with the knowledge and skills to become agents of change. This research plays a role in shaping ethical and impactful green entrepreneurship mindsets and competencies; 4) It fills the gap between theory and practice, as there is still a lack of research that systematically connects SDGs, green entrepreneurship, and biology curricula. This research contributes to the development of applicable learning instruments, rubrics, and modules; 5) It supports SDGs policy and implementation, which serve as a basis for policymakers, educators, and communities to design evidence-based programs that support the achievement of SDGs locally and nationally (Clarisa et al., 2020). Existing studies have shown the great potential of the local wisdom approach to increase the relevance of education and foster environmental awareness. The integration of traditional and modern educational methods within the context of local wisdom is key to achieving meaningful and sustainable learning at both local and global scales (Afnan et al., 2024). Eco-Islamic boarding schools are an innovation for students, Islamic scholars, and even alums to develop Islamic boarding schools based on local wisdom by working together and collaborating as a form of instilling an entrepreneurial spirit in students (Gunawan & Alfarisi, 2023)

The urgency of green entrepreneurship research in the context of the SDGs is an approach that can help bridge the gap between the environment, business innovation, SDG achievement, a sustainable economy, and social empowerment. The importance of innovation in addressing sustainable development challenges is evident in the increasing involvement of academics in this field (Azmat et al., 2023)

The implementation of green entrepreneurship focuses on developing environmentally friendly products and services, such as renewable energy, recycling, and organic farming. Research is needed to identify appropriate technologies and business models that can be implemented locally (Malele, 2021). Green entrepreneurship contributes to SDG 8 (Decent Work and Economic Growth), SDG 9 (Industry, Innovation, and Infrastructure), and SDG 12 (Sustainable Consumption and Production). Green entrepreneurship in the context of the SDGs supports the

development of entrepreneurship curricula and training that instill values of sustainability, ethics, and spirituality, shaping a generation of entrepreneurs who pursue not only profits and benefits but also social and ecological benefits.

Green entrepreneurship knowledge and practices in the context of the SDGs are still limited in terms of data and documented practices (OECD, 2017; Taufiq & Aviyanti, 2022; Meishanti et al., 2023; Meishanti et al., 2024; Meishanti et al., 2025). This interconnected research can uncover barriers, opportunities, and local adaptation strategies, including the integration of local wisdom into green business models. This research also encourages transdisciplinary collaboration, as green entrepreneurship pathways involve environmental, economic, technological, social, and cultural sciences (Aurellia & Nuringsih, 2023). Cross-disciplinary collaboration opens up space for collaborative innovation between academics, businesses, government, and communities. Innovation as an outcome reflects the 'what' or 'what type', with a focus on two aspects: (i) the type of innovation (e.g., product/service, process) and (ii) the form of innovation (e.g., green innovation, inclusive innovation, frugal innovation) (Azmat et al., 2023)

Entrepreneurship is one of the soft skills that need to be developed when participating in 21st-century society. Schools and science learning practices can transform to develop student competencies by integrating science learning with entrepreneurial character. The learning values in question are the basic values of science learning, expressed as scientific processes, knowledge products, and scientific attitudes, combined with an entrepreneurial character. If entrepreneurship and science learning are combined, knowledge will be created that is useful for children's social and economic lives at home and in society. Students must have a high interest, self-confidence, mental autonomy, and a sense of responsibility for the information they currently have to start other special units. Also, Rohmah & Rizqan (2021) stated that no single instruction can meet all students' needs and learning styles. 21st Century Skills: The studies reviewed included a variety of activities that focused on developing 21st-century students through informal learning environments (Hussim et al., 2024). Thus, an adaptive understanding of life skills development can be achieved by designing "flexible and adaptive" learning environments that involve problem-solving rooted in real-world decisions (Kumar, 2016).

Ecopreneurs engage in activities to develop businesses that focus onustainable solutions to reduce negative environmental impacts (Prado et al., 2022). Irawan & Aulia (2022) improve the environment by creating environmentally friendly products and services and by providing a strong network that connects professionals and companies engaged in ecology. Ecopreneurs combine economic benefits with positive environmental impacts. Ecopreneurs in the era of society 5.0 are also equipped with advanced technology to create more efficient, environmentally friendly, and effective products and services, and to incorporate sustainable values, thereby reducing negative environmental impacts (Rasika & Esthi, 2025).

Green entrepreneurship in the context of the SDGs, namely SDG 12, sustainable consumption and production, is integrated into the biology curriculum because it focuses on sustainable consumption and production, natural resource management, and environmental awareness. This integration strengthens education grounded in sustainable values d concrete actions (Anwar, 2022). The implementation of green entrepreneurship in the context of the SDGs for students can aim to encourage a sustainable lifestyle, including in food, energy, and the use of goods (Atmando, 2021), and reduce waste and pollution through recycling, resource efficiency, and changes in consumption behavior (Marliana et al., 2021). Increasing public awareness about the impact of consumption on the environment and overall health can be instilled in students as agents of change from an early age. The link between SDG 12 and the Biology Curriculum because it is very suitable for integrating SDG 12 through: 1) Ecology and recycling topics, with students learning about the food chain, material cycles, and the impact of waste on the ecosystem; 2) Biotechnology and sustainable agriculture, namely the exploration of biological solutions for environmentally friendly food production; 3) Health and nutrition about understanding healthy consumption and its impact on the body and the environment.

Innovation can solve environmental problems while simultaneously providing economic benefits to businesses (Irawan & Aulia., 2022). This is primarily through cost reduction and mitigation, as well as adaptation and resilience-building, which also have social implications (Azmat et al., 2023; Marczewska et al., 2024)

The main goal is to change the mindset and behavior of students to be more aware of the impact of their life choices on the environment and society, and to develop skills to implement a sustainable lifestyle (Andriani et al., 2021; Somwethee et al., 2023) Field learning activities are one

effective way to help students connect academic material with real-world contexts (McKinney, 2023). Students are expected to become agents of change in protecting the environment and encouraging sustainable living in the future (Fibonacci et al., 2020). Where the actors often change modes of transportation, energy consumption, and eating patterns (Luh et al., 2022). Students who learn actively will learn more effectively and consistently when studying a concept related to real life. In active learning, the teacher serves only as a guide and prepares the classroom or learning environment while students actively participate cognitively, emotionally, socially, and physically (Clarisa et al., 2020). Awareness of sustainability is also important because it seeks to encourage the current generation's concern for maintaining the integrity of the environment, as well as the safety, capabilities, welfare, and quality of life of current and future generations (Sari et al., 2024).

Satiti et al. (2024) Entrepreneurship-based learning is one of the important pillars in driving economic growth and development. Rahman et al. (2024) identified measurable indicators of academic achievement in science entrepreneurial thinking skills, including observation, new ideas, innovation, creativity, and social values. To foster an entrepreneurial spirit, it does not have to be in economics or entrepreneurship subjects alone, but can also be fostered in almost all subjects. Rahmatillah et al. (2023) define entrepreneurial characteristics as the attitudes, behaviors, and traits of an entrepreneur in everyday life and in managing his business. Entrepreneurial characteristics are KWU Characteristics inherent in individuals who are able to manage the advantages within themselves and their surrounding environment, so that, in addition to developing superior businesses, they also attract labor from the surrounding community. Advantages of environmentally friendly science entrepreneurship. So that teachers can apply science learning based on local wisdombecause it can increase student activity and student interest in local culture (Rosyidah & Setiawan, 2025): 1) Reducing environmental impact: Reducing greenhouse gas emissions and pollution; 2) Saving natural resources: Saving natural resources such as water, land, and energy; 3) Improving quality of life: Improving people's quality of life by reducing pollution and improving health; 4) Developing green technology: Developing green technology that can reduce greenhouse gas emissions and pollution. This is picture 1. Visualization of Keywords in Articles on Green Entrepreneurship with SDGs:

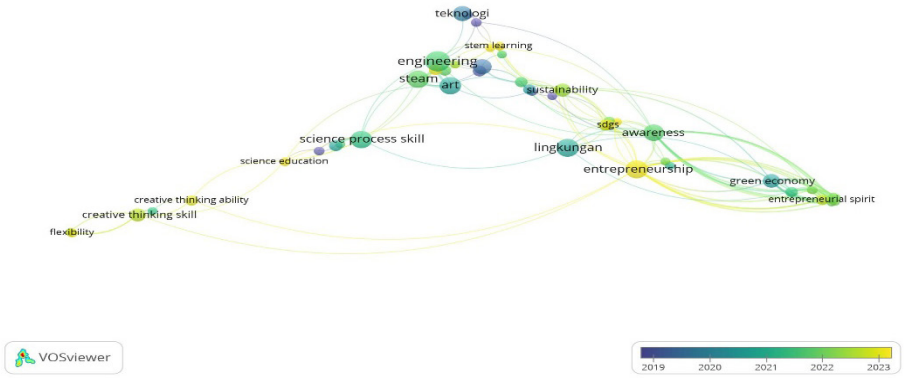

Figure 1. Visualization of Keywords in Articles on Green Entrepreneurship with SDGs (source: VOSviewer)

The shift towards brightness in 2023, visualized by shades of yellow, symbolizes the increasing intensity, relevance, and novelty of the research themes. The novelty of the 2023 research is reflected in the increasingly bright yellow visualization. This confirms that entrepreneurship, the SDGs, and creative, innovative skills in supporting a green economy are not only relevant but also central to academic innovation and real-world practice. The Sustainable Development Goals (SDGs) are a key reference in cutting-edge research. The yellow color indicates that research linking entrepreneurship to the SDGs is increasingly relevant, as it supports the 2030 global agenda. Novelty arises from how researchers operationalize the SDGs into green economy curricula, policies, and practices. The 2023 research highlights the importance of creative skills and innovative thinking as core competencies. The novelty lies in measuring these skills within the context of STEAMS (Science, Technology, Engineering, Arts, Mathematics, Spirituality)

related to the SDGs. Creativity is no longer viewed solely as an individual talent but rather as a strategic skill to support green entrepreneurship. Research in this area has novelty value because it: 1) integrates the global SDGs framework into a local context; 2) develops a sustainable entrepreneurship model; 3) develops a creative skills measurement instrument to support green economic transformation.

In the context of a green economy, entrepreneurs are required to care about environmental issues and their impact on people's lives by practicing entrepreneurship (producing goods/services, buying and selling goods/services) and paying attention to aspects of balance between economic, environmental, and social aspects (Ardianingsih & Meliana, 2022). An entrepreneur is someone who creates a new business by taking on risks and uncertainties to achieve profit and growth by identifying opportunities and combining the resources needed to establish it. In general, the objectives of establishing a green company are grouped into four, namely profit, company survival, growth, and social responsibility (Koe Hwee Nga & Shamuganathan, 2010). According to (Meishanti, 2021; Aurellia & Nuringsih, 2023; Meishanti et al., 2025), green entrepreneurship is an idea to help solve sustainable development problems, as well as being a major movement in building the country's economy: 1) Achieving SDGs, local wisdom of Islamic boarding schools, and their relation to sustainable development goals (SDGs). How local wisdom can contribute to achieving SDGs, for example, in the fields of quality education, environment, and health; 2) Local wisdom-based science learning in Islamic boarding schools can be carried out through integration with the objectives of the SDGs (Sustainable Development Goals). The context of local wisdom-based science learning is knowledge gained from centuries of experience in sustainably utilizing the environment and natural resources. Local wisdom-based science learning can complement science and biology education by incorporating relevant case studies and practical examples, helping students understand and appreciate their cultural heritage.

Project-based learning in Islamic boarding schools is an approach to the learning process that combines project-based practice as a medium for learning and skill development, actively involving students in completing projects to encourage critical thinking, creativity, and practical skills. The project that was once developed at the Islamic boarding school focused on the health of students who experienced itching, tinea versicolor, scabies, and ringworm, due to the use of shared towels, changing clothes every 2 days, and collaboration with KH Universitas A. Wahab Hasbullah to conduct soap-making training. The guardians themselves, as practitioners in the training, because the sons and daughters who had experienced itching in the Islamic boarding school already had soap brands, which were even sold in stores. So that cooperation was established between the guardians and KH Universitas A. Wahab Hasbullah.

The formulation of the problem "Green Santripreneur Transformation: Building Sustainable Entrepreneurship Based on Science and SDGs in Islamic Boarding Schools" is as follows: 1) How is the analysis of the implementation process of the Green Santripreneur project in Islamic boarding schools as an effort to build sustainable entrepreneurship in Jombang?; 2) How is the identification of the integration of scientific values and SDGs principles at each stage of the entrepreneurship project in the Islamic boarding school environment in Jombang?; 3) What is the role of students and Islamic boarding schools in developing a green entrepreneurship model based on spirituality, science, and environmental awareness in Jombang?; 4) What are the strategic recommendations for the development of Green Santripreneur as a sustainable entrepreneurship model that can be replicated in other Islamic boarding schools?.

The objectives of the research on "Green Santripreneur Transformation: Building Sustainable Entrepreneurship Based on Science and SDGs in Islamic Boarding Schools" are: 1) To analyze the implementation process of the Green Santripreneur project in Islamic boarding schools as an effort to build sustainable entrepreneurship; 2) To identify the integration of scientific values and SDGs principles in each stage of the entrepreneurship project in the Islamic boarding school environment; 3) To explore the role of Islamic boarding school students and Islamic boarding schools in developing a green entrepreneurship model based on spirituality, science, and environmental awareness to be applied in the learning process; 4) To develop strategic recommendations for the development of Green Santripreneur as a sustainable entrepreneurship model that can be replicated in other Islamic boarding schools.

The theoretical orientation used in this study is a phenomenological one, a research approach that emphasizes individuals' subjective understanding of a phenomenon. This approach emphasizes how humans experience and attach meaning to an event. This orientation was chosen

to provide direct, subjective experiences for students and teachers during their time at the Islamic boarding school, so that researchers can better understand students' experiences there. This approach allows exploration of how students develop science skills through a scientific approach and how they feel the benefits. By exploring the meaning given by the research subjects, this approach helps reveal the nature of their experiences in the learning process. Researchers act as key instruments who must collect data by visiting data sources directly to understand, describe, and explain the conditions and behavior of students participating in protecting the environment related to sustainable living and sustainable santri arwaness based on green entrepreneurship. This research is exploratory in nature, allowing the identification of variables to be integrated into theory in a larger project, where the purpose is to develop substantive theory (Glaser & Strauss, 1998). Thus, project-based research is acceptable for describing and explaining fundamental social processes that shape interactions and behavior (Karuntu et al., 2022).

METHODS

This study uses a descriptive qualitative approach to describe and explain the events, phenomena, and social situations studied. According to Bogdan and Taylor, qualitative research is a research procedure that produces descriptive data in the form of written or spoken words from people and observed behavior. Qualitative research is also defined as a strategy for finding meaning, understanding, concepts, characteristics, symptoms, symbols, or images of a phenomenon, focused and multi-method, natural and holistic, prioritizing quality, using several methods, and presented narratively in scientific research. This research is natural, reasonable, and in-depth by focusing on real, subjective, and interactive events with participants (Waruwu, 2024).

The qualitative research used in this study employs grounded theory, with an emphasis on santripreneurs aligned with the Sustainable Development Goals (SDGs). Grounded theory is a methodology used by researchers to develop theories inductively from data, without starting from a theory and then trying to "prove" or "refute" it (Karuntu et al., 2022). Grounded Theory is a way of developing theories inductively from data about a behavioral pattern. Budiasih & Nyoman (2014) mentions several primary characteristics of grounded theory: 1) the focus of the research is directed at processes related to a substantive topic; 2) data collection (which is carried out simultaneously with data analysis) is carried out using theoretical sampling; 3) data analysis is carried out, while making continuous comparisons and asking questions about the data obtained; 4) when analyzing data to emerge categories, core categories are identified; 5) the identified core categories are then developed and formulated into a theory; and 6) during the research, the researcher makes notes (memos) to describe ideas related to the data and coded categories.

The selection of informants uses theoretical sampling; informants are chosen not only because they are relevant, but also because they can develop and test the theoretical framework being built. The selection of informants is carried out in stages and flexibly, according to the needs of the analysis, thereby strengthening the categories that emerge. The selection is not rigidly determined at the beginning, but develops throughout the research process, not only choosing the "easy to reach", but also those that really contribute to the construction of the theory. Researchers can show that the data collected support the formation of new concepts, not just the repetition of old findings. The stages carried out are as follows: 1) Initial stage, selecting 1st semester biology education students who are currently working on a scientific paper writing project to see how the relationship between school students who choose to live in Islamic boarding schools and integrate innovative creative skills in learning both in Islamic boarding schools and at school; 2) Initial analysis, findings emerged that creativity is influenced by the learning process that students have taken in Islamic boarding schools and at school; 3) The next stage, adding informants from 3rd semester students who are active in environmental organizations to deepen the category of "green entrepreneurship" along with alumni of Islamic boarding schools who attend Islamic boarding schools, especially at the high school level (Madrasah Aliyah); 4) In the next stage, if the dimension of spiritual values appears, researchers can add students who participate in religious or community activities based on spiritual values, SDGs or awareness.

The field research was conducted in August 2024 – October 2025, with informants comprising 30 Islamic boarding school students from Jombang, 10 samples of Islamic boarding school students in Jombang, and alums of Islamic boarding schools involved in the research. The analysis was carried out using the following software: 1) Bibliometric analysis and research recency, namely using VOSviewer by mapping research trends, topic recency, and relationships

between keywords (for example, the color yellowing in 2023); 2) Biblioshiny (R), for bibliometric analysis based on Scopus or Web of Science. Meanwhile, creativity and learning analyses were conducted using Google Forms, Excel/Sheets, and Google Drive to collect and process data from the creative skills survey.

Qualitative research procedures using the grounded theory method consist of several stages that are carried out simultaneously. These stages range from the problem formulation stage to the final stage, which is writing a research report. The following are the stages carried out according to (Grounded Theory Creswell, 2005; Oktaria et al., 2023) carried out by researchers as follows: 1) Determining the grounded theory design; 2) Identifying the process being studied such as formulating the problem; 3) Obtaining approval and seeking access to the research setting; 4) Carrying out relevant data collection procedures until the researcher is sure that the data can be used as a basis for developing a theory (theoretical sampling); 5) Carrying out the coding process, namely activities carried out by researchers at the data collection stage; 6) Carrying out selective coding and developing theories, namely advanced procedures from axial coding to re-examine the relationship between one category and another. 7. Validating the theory, namely the procedural stage for analytical thinking about whether the concept developed is relevant, contextual, and in accordance with the reality experienced by participants.

Data collection techniques are the most important step in a study, because the main purpose of a study is to obtain data (Sugiyono, 2019). Data collection can be done in several ways. The data collection techniques used in this study include interviews, observations, and informant documentation. Data analysis is the process of systematically searching for and compiling data obtained by researchers during data collection activities, so that the data can be easily understood and communicated to others. Data analysis in qualitative research is conducted from the researcher's initial entry into the field through the end of the study. Data analysis steps according to Miles & Huberman (1994) in the qualitative research methodology book are presented in Figure 2.

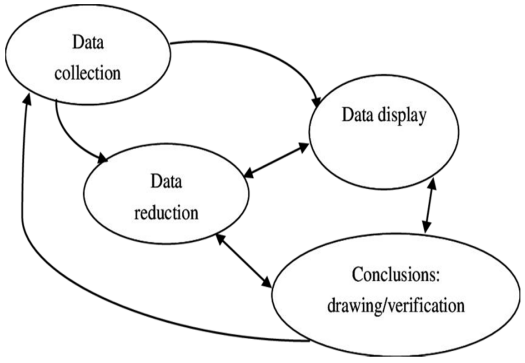

Figure 2. Miles and Huberman Data Analysis Technique

Data Reduction includes sorting the collected data to what is needed. Data reduction is a form of analysis that groups, filters, removes unnecessary data, and organizes the reduced data to provide a deeper picture of the observation results and make it easier for researchers to find what they need. The field data is quite extensive, so it needs to be carefully recorded and reduced in detail. The reduced data focuses on sustainability with a STEAM approach to build sustainable living and sustainable awareness.

In Data Display, the reduced data is presented ed in a pattern that makes it easier to understand. Researchers group data systematically, so that it is easier to understand the interaction between parts in a complete context. The data displayed will make it easier to understand what is happening and plan further work based on what has been understood. The data presented in this study is in the form of a table containing a set of santripreunership transformation analysis data from several Islamic boarding schools in Jombang.

In Conclusion Drawing (Verification), researchers formulate new findings from the research and then review the data collected. Researchers in this process summarize the main findings regarding students' process skills based on the reduced and presented data, so that a comprehensive understanding is obtained to answer the

research objectives (Daruhadi & Sopiati, 2024). Checking the validity of data is a standard for the truth of research data that emphasizes data and information over attitudes and the number of people. Data validity is equivalent to the concepts of validity and reliability in qualitative research and is adjusted to the demands of science, its own criteria, and paradigms. To determine the validity of the data, examination techniques are needed, and their implementations are based on several specific criteria (Husnullail et al., 2024). Data validity tests on qualitative data include credibility tests (interval data validity), transferability (external validity), dependability (reliability), and confirmability (objectivity) (Adlini et al., 2022).

The data validity test used in this study is the credibility test. The credibility test in qualitative research is called internal validity. Data can be declared credible if there is a similarity between what the researcher reports and what actually happens to the object being studied (Mekarisce, 2020). Qualitative data credibility tests can be carried out in several ways, including extended observation, research persistence, triangulation, peer discussion, negative case analysis, and member check. The data credibility test used in this study is triangulation. Triangulation is a data-checking technique that uses something other than data for verification or comparison (Husnullail et al., 2024). There are three types of triangulation used as data validity-checking techniques: source, technique, and time triangulation. The triangulation used in this study is source triangulation, namely, the researcher checks or compares data obtained from various sources. The data-checking stage using source triangulation allows researchers to compare results from various sources to assesshe accuracy of the information obtained (Mekarisce, 2020).

RESULTS AND DISCUSSION

This study aims to develop a theory that explains the process of transforming students into green santripreneurs entrepreneurs who not only uphold Islamic values, but are also committed to environmental sustainability and the principles of the Sustainable Development Goals (SDGs). The main focus of this study is to explore how Islamic boarding schools, as Islamic educational institutions, can shape the character and competencies of green entrepreneurs grounded in science and sustainability values (Meliani & Panduwinata, 2022). The grounded theory approach was chosen for several fundamental reasons, namely a) theoretical vacuum: No theory explains explicitly the dynamics of the formation of green santripreneurs in the context of Islamic boarding schools and the integration of SDGs values; b) Inductive approach: Researchers do not intend to test existing theories, but rather build new theories that are born directly from field data; c) Contextual complexity: The process of transforming students into green entrepreneurs is complex, dynamic, and highly influenced by the local context of Islamic boarding schools, so that a flexible and open grounded theory approach is very relevant.

This research was conducted in several Islamic boarding schools in Jombang Regency, East Java, that have shown initiatives in developing sustainability-based entrepreneurship, namely Islamic boarding schools with santripreneur business units by running various business units such as bread, snacks, and fisheries businesses managed by students as part of the entrepreneurship program (Santoso et al., 2023). The research design is guided by a paradigm and approach in accordance with exploratory and constructive objectives, as shown in Table 1.

Table 1. Research Design

Research Design	Explanation
Paradigm	Constructivist – emphasizes the meanings that are socially constructed by individuals in their context.
Types of Grounded Theory	Constructivist Grounded Theory (Charmaz) – because researchers want to understand how students and administrators of Islamic boarding schools construct meaning and transformation processes.
Unit of Analysis	Students, Caretakers of Islamic Boarding Schools, and Managers of Islamic Boarding School Business Units
Data Approach	Qualitative – through in-depth interviews, participant observation, and documentation

Research to answer the question "How is the process of transforming students into green santripreneurs based on science and the principles of Sustainable Development Goals (SDGs) in Islamic boarding schools in Jombang Regency?" This question serves as the basis for exploring the internal dynamics of Islamic boarding schools in developing young entrepreneurs who are not only technically competent but also possess ethical and environmental insights. Based on the results of the initial field study and literature review, the process of transforming students into green santripreneurs in Islamic boarding schools as occurred in Islamic boarding schools in Jombang can be identified through five main stages: 1) Awareness Building: a. Students are introduced to the importance of economic independence and environmental responsibility through lectures, comparative studies, and thematic discussions; b. Islamic values are contextualized with the principles of sustainability and business ethics, forming an initial awareness of the importance of entrepreneurship that is oriented towards the public interest; 2) Capacity Building, students are equipped with technical skills such as: integrated organic farming and animal husbandry, waste processing (e.g., BSF maggot cultivation), culinary arts, and healthy food production. Introduced to the concept of applied science and appropriate technology as a basis for business innovation; 3) Empowerment, students are actively involved in the management of Islamic boarding school business units. Given space to innovate, make decisions, and manage business aspects such as production, financial records, and marketing; 4) Internalization of SDGs Values, business activities are directed to support SDGs goals, such as: a. Poverty alleviation (SDG 1); Quality education (SDG 4); b. Responsible consumption and production (SDG 12); c. Action on climate change (SDG 13); d. These values are integrated into daily practices and the vision of the santri business (Gunawan & Alfarisi, 2023).

The transformation of santri into green santripreneurs is not just an economic process; it also involves spiritual, social, and ecological dimensions. Islamic boarding schools have great potential as sustainable entrepreneurship incubators that combine local values (Islam, Islamic boarding school wisdom) with global values (SDGs, technological innovation). This process is dynamic and contextual, so a deep understanding from the actors' perspective is very important for buildingelevant and applicable theories (Agusti, 2022).

The Open coding stage is the initial stage in grounded theory data analysis, where researchers break down raw data (interview results, observations, documentation) into small, meaningful units called codes. These codes are then categorized to find initial patterns and concepts, with the following open coding steps in the study: 1) Data Transcription, a. Interviews with students, caregivers, and business unit managers are transcribed verbatim, which is the process of copying conversations or voice recordings into word-for-word text, without removing or changing anything from the original content, b. Observations of student entrepreneurial activities (e.g., BSF maggot training, organic farming, and convection production) are recorded in a field journal; 2) Initial Coding and Code Grouping (Table 2).

Table 2. Initial Coding and Code Grouping

Interview Quotes	Initial Code	Initial Category
"We learned how to make fertilizer from kitchen waste."	Waste utilization, Local innovation	Green entrepreneurship practices
"I became more confident after taking the training."	Training effects, increased motivation	Transformation of students' mindset
"We were taught that trading is worship."	Spiritual values, Islamic business ethics	Integration of Islamic and economic values
"We were invited to discuss SDGs and the environment."	SDGs Education, Environmental Awareness	Integration of Islamic Values and SDGs

Initial Coding Results and Code Grouping, several initial categories emerged, namely: a) Transformation of students' mindsets; b) Integration of Islamic values and SDGs; c) Application of science in entrepreneurial practice; d) The role of Islamic boarding schools as entrepreneurship incubators; e) Challenges and obstacles for students in entrepreneurship. Then an analytical memo was obtained, an important process in qualitative research that serves as a reflective and conceptual note for the researcher during data collection and analysis. It was found that "There is a strong relationship between spiritual values and student motivation in running a business.

This can be the basis for a theory of spiritual-based green entrepreneurship."

Sustainable entrepreneurship in Islamic boarding schools is formed through the integration of science-based green entrepreneurship learning and the SDGs, which facilitate the internalization of sustainability and spiritual values, thereby giving rise to entrepreneurial behavior oriented towards ecological, social, and spiritual sustainability. The following are the steps of transformation into substantive theory through: 1) identification of main categories; 2) Core categories; 3) Relationships between categories (conceptual propositions); 4) Conceptual Model (substantive flow) as presented in Table 3.

Table 3. Identification Of Main Categories

Identify the Main Categories	Indicator	Achievement Results
Sustainable entrepreneurship	final goal (result)	Sustainable entrepreneurship is not just about generating economic profit, but also about creating long-term impacts that balance economic, social, environmental, and spiritual aspects. (Andriyati et al., 2024) state that sustainable entrepreneurship aims to create new businesses by balancing three main aspects: economic, social, and environmental.
Green entrepreneurship learning model	strategy / method	The science-based and SDGs-based green entrepreneurship learning model in Islamic boarding schools uses project strategies, problem-solving, hands-on experience, community service, transdisciplinary collaboration, and green business simulations to internalize sustainability values while building environmentally friendly entrepreneurial skills (Nisa & Nugrahaeni, 2024). The implementation of environmental conservation as the main principle for managing environmentally friendly Islamic boarding schools is a manifestation of great concern about environmental damage and natural disasters in Indonesia, due to a lack of knowledge of sound natural resource management and environmental management.
Science-based	knowledge base	The green entrepreneurship learning model in Islamic boarding schools is grounded in science as the core of knowledge, combining the natural, social, and technological sciences with spiritual values, resulting in sustainable entrepreneurial practices grounded in scientific evidence and oriented towards the SDGs. One of these models is the GEL Learning Model. Thus, "science-based" is not just a label but an epistemological foundation: green business taught in Islamic boarding schools must be explainable, testable, and scientifically justified, then enriched with spiritual and sustainability values. Afnan et al. (2024) state that science education, as a broader umbrella, has the potential to bridge all these concepts. By integrating local wisdom, sustainability principles, and effective science learning methods, science education can become a powerful tool for shaping environmentally conscious global citizens, rooted in their culture and equipped with a strong scientific understanding.
SDGs-based	global value orientation	The SDGs-based green entrepreneurship learning model with a global value orientation in Islamic boarding schools integrates the global sustainability agenda into local practices, enabling students not only to build sustainable businesses for their communities but also to become part of the global movement to protect the earth and achieve socio-ecological justice. Sustainable development focuses on meeting the needs of the present without harming future generations by balancing economic development, social welfare, and environmental sustainability (Azzulfa & Nugraheni, 2024).
Islamic boarding school	socio-spiritual context	Islamic boarding schools, as socio-spiritual contexts, provide a collective environment and religious values that integrate science-based green entrepreneurship learning with the SDGs, thereby producing students who are oriented not only towards economic gain but also towards social, ecological, and spiritual sustainability (Nisa & Nugrahaeni, 2024). One concern of Islamic boarding schools regarding the environment is the integration of environmental education into learning.

The transformation step for the Core Category is "Integrating sustainability values and spirituality through science-based green entrepreneurship learning and the SDGs." The relationships between categories (conceptual propositions) include: 1) If Islamic boarding schools implement a green entrepreneurship learning model, students will internalize sustainability values; 2) Integrating science and the SDGs strengthens the relevance of learning to global challenges; 3) Islamic boarding school spirituality strengthens moral motivation in sustainable entrepreneurship practices.

The Conceptual Model (substantive flow) of science-based green learning and the SDGs, with the internalization of sustainability values and the strengthening of Islamic boarding school spirituality as a form of behavioral transformation to foster sustainable entrepreneurship among students.

This research provides theoretical innovation by developing a green entrepreneurship learning model grounded in science, the SDGs, and Islamic boarding school spirituality, and methodological innovation through transdisciplinary learning strategies relevant to Islamic boarding school education policies and the green entrepreneurship curriculum. This is to achieve the Sustainable Development Goals of creating students who care about the environment and who embodynvironmentally conscious individuals (Nisa & Nugrahaeni, 2024). The relationship between categories is presented in Table 4.

Table 4. Relationship between Categories

Supporting Category	Relationship with Core Categories
Transformation of the Mindset of Santri	The initial process that enables students to embrace the values of entrepreneurship and sustainability
Integration of Islamic Values and SDGs	Becoming a normative and spiritual foundation in green entrepreneurship practices
Application of Applied Science and Technology	To be a tool to realize efficient, environmentally friendly, and sustainable business practices.
The Role of Islamic Boarding Schools as Incubators	Providing space, support, and learning systems that shape an entrepreneurial ecosystem
Challenges and Obstacles	Becoming a factor that tests resilience and adaptation in the transformation process

The researcher developed a theoretical model as follows: "The transformation of students into green santripreneurs occurs through the process of internalizing sustainability values facilitated by an integrative pesantren ecosystem, combining Islamic values, SDGs principles, and applied science in contextual and independence-oriented entrepreneurial practices. Based on the results of open coding and axial coding, the researcher identified the category "Internalization of Sustainability Values in the Pesantren Ecosystem", where this category is central because the entire process of transforming students into green santripreneurs is rooted in how sustainability values (both spiritual, social, and ecological) are integrated into the life and education of the pesantren, as follows: 1) Internalization of Sustainability Values as the Core of Transformation.

The results of the study show that the transformation of students into green santripreneurs is not only technical, but also ideological and spiritual. Sustainability values instilled through religious education, entrepreneurship training, and direct practice form the main foundation for the character of independent, environmentally aware students. Entrepreneurship education is critical for Islamic boarding schools to prepare students to enter the world of work and business, according to Hidayat et al. (2025). Based on the character education and social transformation approach, sustainability values are internalized through: a. Religious education: Connecting the concept of sustainability with Islamic teachings; b. Entrepreneurship training: Integrating ethical and sustainability values into the business curriculum; c. Direct practice: Students are involved in real projects such as making environmentally friendly soap, organic farming, or waste processing. The economic empowerment of Islamic boarding schools does not only focus on product management but also integrates entrepreneurship education to students through real activities (Rachman & Tidjani, 2024; Junaidah et al., 2025) 2) Transformation of the Mindset of Students, Students experience a change in their perspective on entrepreneurship, from merely an economic activity to a form of worship and social contribution. Training, direct experience, and role models from the

caretakers of the Islamic boarding school are the main triggers for this change. Increasing entrepreneurial motivation through seminars, lectures, training and the like from various parties such as community service activities is always needed to maintain, grow and instill an interest in entrepreneurship for the younger generation as provisions to then enter society according to Suryani et al. (2024), while according to Hidayat et al. (2025) by studying entrepreneurship, students can develop their abilities in creating independent and sustainable business opportunities. Suryani et al. (2024) stated that students can obtain entrepreneurial motivationhrough knowledge, training, seminars, internships or learning by doing (Agusti, 2022) entrepreneurship for students is very important, so in addition to students being equipped with reciting the Koran and religious knowledge, students must also be equipped with skills because that way students will not only think about the afterlife but will be productive and productive. This is done by both administrators and all students who participate in activities at the Islamic boarding school, starting from daily activities to entrepreneurial activities. According to Rachman & Tidjani (2024), Santripreneur is the empowerment of students to disseminate their knowledge and expertise in creating new products in accordance with Sharia that prioritize benefits and profits. The stages carried out through the santripreneur program are: socialization, selection, KWU Islamic boarding school, capital, mentoring, and monitoring and evaluation (Meliani & Panduwinata, 2022); 3) Integration of Islamic Values and SDGs, pesantren links Islamic principles such as khilafah, amanah, and maslahah with SDGs goals such as poverty alleviation, quality education, and climate action. This creates a new narrative that becoming a green entrepreneur is part of religious responsibility (Doktoralina et al., 2024). They stated that the principles of Islamic entrepreneurship, including shiddiq, ihsan, and maslahah, provide a strong moral foundation for facing these challenges. The development of the pesantren curriculum as part of improving the quality of national education must be carried out comprehensively, carefully, and thoroughly (kafah), especially related to the quality of pesantren education, as well as its relevance to the needs of society and the world of work, while still using the yellow book as a reference Fiandi et al. (2023). Yuniar et al. (2022) discuss how education related to culture and creativity can help in realizing creativity according to the SDGs; 4) Application of Science and Technology, students are trained to use appropriate technology, such as BSF maggot cultivation, hydroponics, and waste processing. This approach shows that Islamic boarding schools not only teach values, but also science-based skills. This provides students with an opportunity to develop entrepreneurial skills. The existence of environmental management is certainly the main factor for students to have absolute entrepreneurial potential so that students are not only competent in the religious field but also in their economic independence (Gunawan & Alfarisi, 2023); 5) The Role of Islamic Boarding Schools as Incubators, Islamic boarding schools provide a supportive ecosystem: practice space, mentors, initial capital, and marketing networks. This makes Islamic boarding schools an incubator for value-based entrepreneurship. Rachman & Tidjani (2024) stated that Islamic boarding school entrepreneurship is a concept of empowering the Islamic boarding school economy through the formation of a cooperative organization that aims to produce superior halal products that can be accepted in local, national, and international markets, with stages carried out by the Islamic boarding school entrepreneurship program, namely: institutions, HR development, Production, Marketing and capital.

Scientific aspects of applied science and technology can be applied, among others, to optimize the production of Islamic boarding school businesses, such as bread, batik, or Islamic boarding school agriculture, using lean production principles to save raw materials. Environmentally friendly implementation: a) Environmental Science & Renewable Energy: application of biogas from kitchen waste or Islamic boarding school cages, small solar panels for dormitory lighting; b) Waste Management: composting organic waste for Islamic boarding school gardens; c) Separation of plastic waste with the 8R principle (reduce, reuse, recycle, rethink, repair, restore, replace); c) Sustainability, circular economy in Islamic boarding schools: Islamic boarding school business products (e.g. agriculture) can be used internally, sold to the community, then the waste is reprocessed; d) Integration of SDGs with spiritual values: students are invited to understand that protecting the environment is part of worship, the study of environmental fiqh (fiqh al-bi'ah) as a scientific and spiritual basis. Core Science in Islamic Boarding Schools: a) exact sciences, supporting environmentally friendly technologies (biogas, solar panels, compost); b) socio-economic science, efficiency- and sustainability-based Islamic boarding school cooperatives; c) religious science, integration of spiritual values, for example, the concept of trust and maslahah in sustainable business.

In an era of global transformation, Islamic boarding schools are no longer simply bastions of morality but also centers of values-based innovation. As the world faces health, environmental, and economic challenges, Islamic boarding school students are emerging as agents of change by practically combining science, applied technology, and spirituality.

Figure 3 shows hand sanitizer making training at the As-Salafiyyah Asy-Syafi'iyyah Tambakberas Jombang Islamic Boarding School for boys and girls.

Figure 3. Hand Sanitizer Making Training

Under the scientific guidance of academics, students learn how to make hand sanitizer and liquid soap from natural ingredients, namely lime and lemongrass. They study simple chemistry, microbial biology, and processing technology, then package them into products that are not only useful but also environmentally friendly. Behind the bottles they hold are the values of the 8Rs: they reconsider synthetic chemicals, reject hazardous waste, reduce plastic consumption, and reuse containers. They improve their way of life, recycle knowledge, restore their connection with nature, and replace old habits with sustainable practices. This Islamic boarding school has transformed into a living laboratory where students become moral little scientists, combining science, spirituality, and social aspects in one bottle of soap. They not only clean their hands but also purify their intentions: that knowledge should bring benefits, and innovation should support sustainability. This practice embodies the 8R principle: Reduce, Reuse, Recycle, Rethink, Refuse, Repair, Restore, Replace. It rethinks dependence on chemical drugs, rejects harmful synthetic materials, and reduces waste by utilizing local materials. They reuse ancestral knowledge, enhance health paradigms, recycle natural potential, restore human relationships with plants, and replace consumption patterns with self-sustaining production. Students not only learn plant biology, simple chemistry, and microeconomics, but also bring to life spiritual values: that maintaining health is part of maintaining body confidence. This Islamic boarding school has become a transdisciplinary space where science, the social sciences, and religion are combined in concrete practice. Islamic boarding schools (pesantren) have become dynamic spaces for the application of science and technology. Students learn to mix hand sanitizers and liquid soap from natural ingredients and produce traditional medicines based on local plants. They not only understand chemical and biological processes but also bring to life the principles of 8R, a scientific framework for sustainability and a circular economy. These activities shape a new paradigm: from consumers to producers, from users to managers, from learners to doers. Pesantrens have become transdisciplinary laboratories where STEAMS (Science, Technology, Engineering, Arts, Mathematics, and Skills) build an efficient, environmentally friendly, and sustainable future.

Some of the challenges include limited access to technology, initial student resistance, and minimal external support. However, these challenges actually strengthen the transformation process through adaptation and innovation. S'adah & Rahman (2024) stated that the higher prices of Islamic boarding school products compared to similar products on the market remain an obstacle to achieving wider market acceptance; therefore, ongoing education about the benefits of Islamic boarding school products is essential to increase public interest and demand (Jubaedah et al., 2022). So that science learning based on local wisdom can be applied by teachers, because it can increase student activity and student interest in local culture (Rosyidah & Setiawan, 2025).

CONCLUSION

This study concludes that the green entrepreneurship model in Islamic boarding schools represents a conceptual and methodological innovation that integrates Islamic spirituality, science and technology, and ecological awareness. This model not only strengthens the economic independence of Islamic boarding schools but also positions them as centers of transformation towards sustainable development. Thus, Islamic boarding schools have strategic potential as socio-ecological laboratories that connect education, economics, and spirituality within the SDGs framework. This has resulted in a Green Entrepreneurship Living model within the Islamic boarding school environment, and the next step is to implement a STEAM-based green entrepreneurship living-learning model at the MA level to enhance innovative creativity.

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