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**Article**

# Creative Laboratory Assistance in Sustainable Biology Practicums within Islamic Higher Education

Dela Tiara Putri[1]*, Firdha Putri Nadhiwa[2]

[1] UIN Kiai Ageng Muhammad Besari Ponorogo, Indonesia
[2] University of Airlangga, Indonesia

** Corresponding Address: dhelatiaraput@gmail.com*

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**ABSTRACT**

This qualitative study uses a grounded theory approach to investigate the mentoring strategies of biology laboratory assistants at the State Islamic University (UIN) Ponorogo, where laboratory practices integrate scientific inquiry with Islamic values. Data were collected through in-depth interviews with six purposively selected assistants and analyzed iteratively using ATLAS.ti software through open, axial, and selective coding stages. The findings culminated in a theoretical model of "Creative and Sustainable Islamic Laboratory Mentoring." The study revealed that assistants implemented "controlled creativity," operationalized through four main strategies: pedagogical creativity, creative methodological adaptation, supervised scientific autonomy, and sustainability practices. These strategies are fundamentally underpinned by Islamic values, particularly *amanah* (trust), *shura* (consultation), and *khalifah* (stewardship). This model demonstrates how laboratory mentoring can simultaneously achieve pedagogical effectiveness, ecological sustainability, and spiritual meaning, offering a significant framework for science education in Islamic higher education.

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## INTRODUCTION

A biology laboratory is more than just a room equipped with microscopes and scalpels. Within it, students do not merely learn to dissect frogs; they endeavor to comprehend the narrative of life concealed within each organ, a process that necessitates not only technical guidelines but also mentorship that guides both the hand and the mind (Blankesteijn et al., 2024; Cooper et al., 2024; May et al., 2023). However, the path to this understanding is often fraught with obstacles. Limitations such as insufficient microscopes, depleted chemical reagents, or student confusion in comprehending procedural routine (Coyte et al., 2023; Campbell et al., 2022; Chengere et al., 2025).

At the State Islamic University (UIN) of Ponorogo, these challenges are addressed through a unique perspective. Here, the laboratory is not merely for verifying of theory but also

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a space for instilling values-a place where meticulousness in counting species within a vegetation plot can reflect the attitude of *amanah* (trustworthiness), and group discussions on organ functions can mirror the principles of *shura* (consultation) (Schreiber et al., 2024; Firmansyah et al., 2024). It is this vision of integrating knowledge and values that forms the foundation of this research. We specifically focus on six biology laboratory assistants who serve as the frontline in actualizing this vision. They are the individuals who confront student confusion on a daily basis, while simultaneously bearing the responsibility of ensuring that every drop of solution and each procedural step adheres to scientific principles and ethical conduct.

Yet, how do they actually navigate this complex, Dua role? The literature on science education is indeed rich with studies on scaffolding and inquiry-based learning (Munshi et al., 2022; Soomro et al., 2025). However, few studies highlight mentoring strategies emerging from the context of an Islamic Higher Education institution, where creativity in overcoming resource constraints must aign with a commitment to Islamic values (Mohammed et al., 2024; Afrizal, Abdurrahman & Fitriani, 2024; Aksan, 2023). It is this gap this grounded theory study seeks to fill.

Based on this context, this research is designed to answer three primary questions: (1) what mentoring strategies are developed by biology laboratory assistants at UIN Ponorogo? (2) What Islamic values underpin and are integrated into these mentoring to describe the phenomenon of creative-sustainable Islamic lab mentoring?

Through a qualitative grounded theory approach, this study aims not only to map their strategies but also to construct a comprehensive theoretical model. This model is expected to serve as a reference for science educators within Islamic Higher Education institutions in developing laboratory practices that are not only pedagogically effective and ecologically sustainable but also spiritually meaningful.

## METHOD

The study employs a grounded theory approach to develop a theoretical model based on empirical data (Sosa-Díaz & Valverde-Berrocoso, 2022; Lindqvist & Forsberg, 2022; Cheng & colleagues, 2024). Data collection was conducted through- in-depth interviews with six biology laboratory assistants at UIN Ponorogo, who were purposively selected based on their competence and active involvement in mentoring laboratory practicums. The data were analyzed interactively using ATLAS.ti software, proceeding through the stages of open coding, axial coding, and selective coding until conceptual saturation was achieved. The trustworthiness of the data was ensured through triangulation and member checking, while research ethics were upheld by maintaining participant anonymity and obtaining prior informed consent.

## RESULT AND DISCUSSION

Biology laboratory mentoring in Islamic higher education operates within an academic framework that emphasizes both scientific rigor and scholarly ethics. Consequently, the role of laboratory assistants extends beyond ensuring technical procedures are followed; they are also tasked with safeguarding the integrity of the learning process in accordance with Islamic values. In this context, laboratory assistants function as facilitators who exercise guided autonomy: they provide space for student exploration while simultaneously steering the process according to the instructor's standards, laboratory protocols, and ethical principles that position knowledge as a sacred trust (*amanah*). Interview findings reveal that laboratory assistants shoulder a dual responsibility—technical and moral—emphasizing precision, cleanliness, and respect for biological organisms as integral components of Islamic academic ethics (Asmarany, 2024; Memon et al., 2024). This context of values and authority forms the foundation for a

mentoring approach that is not only compliant with SOPs but also adaptive, reflective, and sensitive to religious and sustainability aspects. To provide an initial overview of how this role was identified inductively, Figure 1 presents the results of the open coding, which maps the patterns of actions and responses of laboratory assistants during mentoring sessions, forming the basis for the subsequent axial and selective coding analysis.

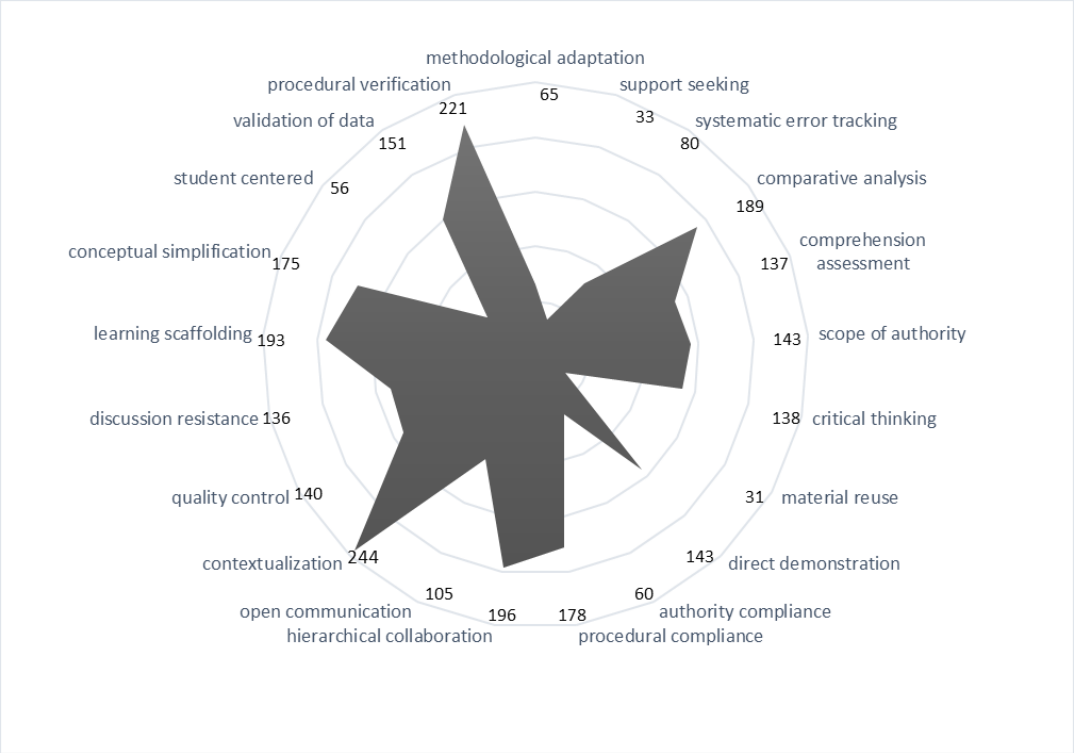


**Figure 1.** Open coding visualization of creative laboratory assistance practices

## Causal Conditions: Structural, Procedural, and Educational Factors

The findings indicate that the patterns of laboratory assistance in the Islamic university context are shaped by the system of academic authority, procedural culture, and the characteristics of novice students. Assistants operate within a hierarchical structure where methodological decisions and practicum modifications must receive prior approval from the instructor, as stated:

"If we want to improvise, we must ask for permission first, because the module is standardized" (P1, P4).

This condition fosters the practice of adaptive teaching strategies that remain anchored in scientific authority, such as method adjustments, live demonstrations, and concept simplification without compromising experimental principles. Adherence to SOPs and quality assurance mechanisms emerged because data accuracy is a priority, evident in the statement:

"Errors in the practicum affect the reports and data, so every step must be checked stage by stage" (P1).

This underscores the moral and scientific accountability within the laboratory. Furthermore, the typically passive readiness of first-year students, who experience participatory learning challenges, prompted the use of student-centered scaffolding, as expressed: "They are still like school students" (P3). Within the context of a value-based biology laboratory, this practice coincides with a commitment to ethically responsible efficiency and reuse of equipment (material reuse and sustainable lab practices), algning with the principles of scientific trustworthiness (amanah) and the stewardship of educational resources (Farley & Nicolet 2023; Freese et al. 2024; Rai et al., 2024). Thus, the structure of

authority, scientific procedures, student readiness, and sustainability ethics collectively form the foundation for the emergence of controlled creativity—a form of pedagogical creativity negotiated within the boundaries of scientific discipline, institutional norms, and Islamic values.

Overall, these causal conditions form the concepptual foundation of the controlled creativity model, where instructional flexibility grows through structured adaptation, procedural verification, and graduated support within the framework of scientific ethics and the spirit of Islamic education. The theoretical relationships between these causal components are mapped in the following axial model to clarify the structure of the theoretical construct derived from the field data analysis.

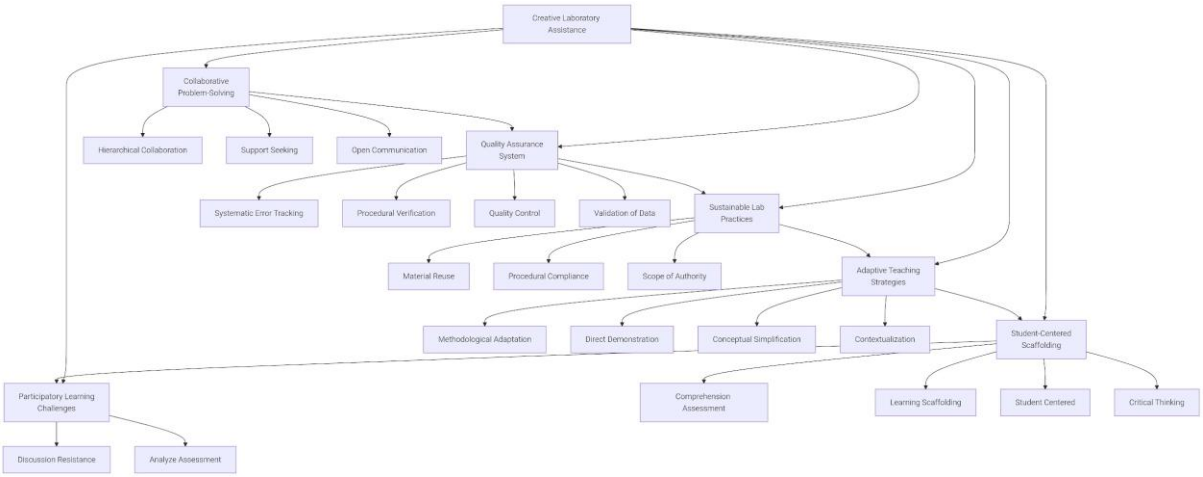


**Figure 2.** Axial coding model of controlled creativity in Islamic biology laboratory assistance

## Intervening Conditions

The laboratory assistance process is influenced not only by structural factors but also by intervening conditions that determine how controlled creativity is implemented in the field. The findings indicate that laboratory assistants operate within a culture of support-seeking, where any methodological modification or problem-solving still requires coordination with the instructor. As one assistant stated: "If in doubt, I consult the lecturer first to avoid missteps" (P4). This affirms that the creativity exercised is collective-supervised, not individually autonomous. On the other hand, student participation is a crucial factor; first-year students tend to be passive and unaccustomed to arguing their points:

"Sometimes they just wait for instructions; they are not yet used to discussions" (P3).

This situation compels assistants to intensively apply student-centered scaffolding, which limits free exploration but ensures the success of fundamental practices. Morever, technical authority boundaries—for instance, the rule that equipment or procedures cannot be altered without permission—reinforce an authority corridor that prevents risky improvisation. Another assistant added: "We are not allowed to modify equipment without permission, for fear of compromising the experiment" (P1). In the ethical realm, Islamic academic values serve as an important moderating force. Prudence, moral reasoning, and the wise management of resources emerged as guiding principles in decision-making, as articulated by P2: "We must be careful and not act arbitrarily. Everything must comply with procedure and laboratory etiquette." Theoretically, these factors support the literature indicating that guided participation and student readiness influence the intensity of scaffolding (Petersen, 2022), and that science

learning in a religious context balances academic authority, epistemic safety, and moral accountability (Bowie et al., 2023).

Facilitators such as instructor guidance, structured modules, and communication among assistants play a vital role in enabling controlled creativity. Assistants emphasized: "When facing difficulties, we discuss it among the assistants first before reporting to the lecturer. This leads to more mature solutions" (P3). Additionally, assistants employ critical thinking prompts to encourage students to understand the connection between laboratory work and the real world. For example, when studying the respiratory system in a lab model, they ask: "If we change this variable, what would be its impact on the human body?" (P6).

**Pedagogical Creativity**

Building upon the framework of guided autonomy previously outliend, the laboratory assistant implement pedagogical creativity through concrete strategies designed to mentor novice students in biology practicums. These strategies emphasize graduated scaffolding, critical dialogue, live demonstrations, and concept simplification, aligning with the principles of Islamic learning ethics, such as patience, mentorship, and propriety (*ta'lim al-mutawassit*). The implementation of these strategies is evident in the following participant excerpts:

"I demonstrate the dissection method first… then they try it themselves." (P4)

"They need an explanation first before they can perform the action." (P5)

The assistants typically begin with conceptual explanations and demonstrations, after which students are given the opportunity for independent practice coupled with discussion. Guided questioning is employed to hone critical thinking and scientific contemplation (*tafakkur*), for instance: "In your opinion, what is the function of this organ?" (P1, P3).

**Table 1.**

| Strategy | Implementation Example | Impact on Students |
|---|---|---|
| Graduated Scaffolding | demonstation before students undertake independent practice. | Students gain greater confidence and procedural understanding. |
| Critical Dialogue | guided questioning: "what is the function of this organ?" | Sharpens critical thinking and scientific contemplation (*tafakkur).* |
| Concept Simplification | Explaining module content using everyday language. | students grasp practicum concepts more easily. |
| Observation + Practice | students follow an example and then proceed to indepent practice. | Enhances learning autonomy and technical skills. |

Overview of Practical Pedagogical Creativity Strategies

**Creative Methodological Adaptation**

After pedagogical creativity was implemented, laboratory assistants developed creative yet controlled methodological adaptations, also known as frugal science or contextual laboratory innovation. This strategy arose from limited resources, student preparedness, and the need to maintain scientific rigor and Islamic values (Byagathvalli et al., 2021; Manishimwe et al., 2024).

This approach emphasized guided flexibility, where improvisation of tools and materials was still validated by procedures and supervised by the lecturer. One assistant explained:

"I explained in simpler language so they could better understand the module." (P5)

"I suggested using KOH solution with an adjusted soaking time to keep the experiment running." (P6)

This adaptation also allowed students to learn contextual problem-solving, where they were asked to propose logical and safe alternative solutions when faced with limitations, such

as a broken microscope or limited chemicals. This strategy emphasizes scientific endeavor and sustainability, in accordance with the principle of istishlah in Islam (Masters, 2024; Freese, 2024).

| Problem | Imprisation Strategy | Impact on the Practicum |
|---|---|---|
| Microscope malfunction | Comparing samples with online references or module illustrations when microscope observation results are unclear. | Data analysis can proceed using valid visual references. |
| Limited chemical reagents | Reusing a previously used $H_2O_2$ solution for cleaning skeletal preparations across multiple student groups. | Conserves expensive and limited chemical supplies, allowing the practicum to continue for all groups. |
| Uneven lighting conditions | Rearranging group workstations based on lighting needs, deviating from the standard laboratory layout. | Observation quality is optimized for all groups. |
| Overly technical module | Explaining concepts using simpler language and breaking down instructions into more manageable steps. | Students gain a better understanding of the practicum's underlying concepts and procedures. |

**Table 2.** Examples of Methodological Adaptation in the Laboratory

Literature supports that frugal innovation improves motivation, conceptual understanding, and critical thinking skills in resource-constrained settings (Masters, 2024; Fajrin, 2023; Rams et al., 2024; Nicol et al., 2022). In Islamic value-based laboratories, this methodological adaptation also emphasizes responsibility, material efficiency, and scientific integrity, thus maintaining creativity. Furthermore, this strategy emphasizes contextual explanation, connecting laboratory practices to real-life phenomena. For example, when studying frog anatomy, students are asked: "This is red, what is its function?" (P3). This approach encourages students to relate experiments to real-life biological concepts, while simultaneously practicing critical thinking and scientific reflection within an Islamic ethical framework.

**Support Seeking & Systematic Error-Tracking: Supervised Scientific Autonomy**

Laboratory assistants (Aslab) develop a culture of support-seeking and systematic error-tracking to maintain the integrity of experiments and guide students. Rather than engaging in individual, freewheeling improvisation, each solution step is preceded by consultation with both fellow assistants and the lecturer, a practice that reflects the Islamic principles of *shura* (deliberation) and *amanah* (responsibility).

Example quote from the field:

"The lab assistants also often gather to discuss problems faced by students. If we're still confused, we contact [the lecturer]." (P3) (Describing tiered support-seeking)

"So we follow the steps the students take, so we find errors here, errors there." (P1) (Describing systematic error-tracking)

**Table 3.** Supervised Autonomy Practices in the Laboratory

| Strategy | Implementation | Impact |
|---|---|---|
| Support Seeking | Discussion among laboratory assistants (Aslab) prior to consulting issues with the lecture. | Solutions are more refined and reliable, minimizing the risk of error. |
| Error-Tracking | Re-cheking student procedures and data step-by-step to trace the source of mistakes. | Students understand the importance of accuracy, meticulousness, and responsibility in every step. |
| Collaborative Reflection | Conducting a joint post-practicum evaluation to discuss errors and improvements for subsequent sessions. | Students learn from mistakes and develop a critical and reflective mindset. |

## Sustainability Practices: Eco-Lab as Islamic Stewardship

Laboratory assistants actively implement sustainable laboratory practices to instill both ecological responsibility and scientific ethical integrity. These strategies include material reuse, material efficiency, and responsible waste management, which align with the Islamic principles of khalifah fil ardh (stewardship on earth) and istishlah (seeking benefit).

Example quote from the field:

"We reused the [$H_2O_2$] solution that had been used to clean skeleton A to clean skeleton B. We were successful; skeleton B was as clean as skeleton A. As a result, the solution can be used multiple times to clean skeletons." (P4) (Illustrate the principle of material reuse)

"We proposed boiling the skeletons before burying them to soften the flesh and make them easier to clean. This speeds up the process and ensures the skeletons don't disintegrate." (P4) (Illustrate innovations for process and resource efficiency)

**Table 4.** Sustainable Practice in the Laboratory

| Strategy | Implementation | Impact |
|---|---|---|
| Material Reuse | Reusing chemical solution (e.g., $H_2O_2$) for multiple samples as long as they remain effective. | Reduces the volume of chemical waste and expenditure on consumable materials. |
| Process Efficiency | Initiating pre-tretment (such as boiling)before the main decomposition specimen preparation and minimize structural damage. | Saves time, labor, and materials, while ensuring more optimal results. |
| Resource Optimization | Sharing samples or collaborating with other groups when task distribution is uneven. | Ensure all groups can complete the practicum without requiring excess materials. |

This approach emphasizes the integration of Islamic values in the laboratory: creativity and adaptation remain active, but always consider sustainability, safety, and scientific ethics. Students learn that innovation in the laboratory is not only a technical matter, but also part of their responsibility as stewards of the earth (khalifah) who must use resources wisely (tawazun), as demonstrated by literature emphasizing sustainability ethics in religious-based science education and sustainable laboratory practices in higher education (Al-Barakat, 2025).

## Consequences/Outcomes

Laboratory mentoring that applies pedagogical creativity, creative methodological adaptation, supervised autonomy, and sustainability practices yields various positive consequences, both for students and for the quality of the lab work. In terms of learning outcomes, students demonstrated improved understanding of biological concepts, data analysis

skills, and more mature critical thinking skills. Students who were initially passive began to actively ask questions and propose simple hypotheses, for example: "Why does it have to be buried first? Why not just put it in the heater?" (P4).

Spontaneous discussions also emerged among them, such as asking each other, "What part is this?" while seeking a shared definition (P5). The Aslab guidance process, which encourages argumentation and step-by-step verification, has pushed students from merely hands-on to minds-on, where they not only carry out procedures but also understand the rationale behind them and dare to ask critical questions. This behavioral change confirms that scaffolded teaching and contextual problem-solving help students internalize concepts more deeply, while connecting laboratory practices to real-life phenomena. The literature shows that guided participation and frugal innovation foster problem-solving and critical thinking skills, especially in resource-limited contexts (Irwanto et al., 2024; Shahid et al., 2023).

In terms of quality outcomes, laboratory practices become more controlled and valid. The systematic use of error tracking and collaboration between assistants ensures accurate data, while safe and efficient methodological adaptations maintain the integrity of the experiments. Students also begin to understand the importance of procedural accuracy, resource utilization, and ethical principles, as seen in the statement:

"If it doesn't follow the procedures stated in the manual... the lab has to be repeated. Whatever it is, it has to be repeated." (P2)

Furthermore, the sustainability of the laboratory is becoming increasingly prominent. Reusing solutions, efficient preparation processes, and collaboration between groups not only increase the effectiveness of the lab but also instill the values of stewardship (khalifah fil ardh) and scientific trustworthiness, as reflected in the initiative:

"The [$H_2O_2$] solution that was used to clean frame A, then we tried to reuse it to clean frame B... the solution can be used multiple times." (P4)

In other words, the laboratory is not only a place for technical practice, but also a vehicle for learning Islamic values through concrete actions. Overall, this combination of creative and controlled strategies results in an integration of theory-practice-ethics, where students learn to conduct experiments correctly, think critically, and take scientific and moral responsibility. Figure 3 presents the final model resulting from the grounded theory analysis, which illustrates the relationship between mentoring strategies and the consequences achieved, both at the individual student level and at the laboratory quality level.

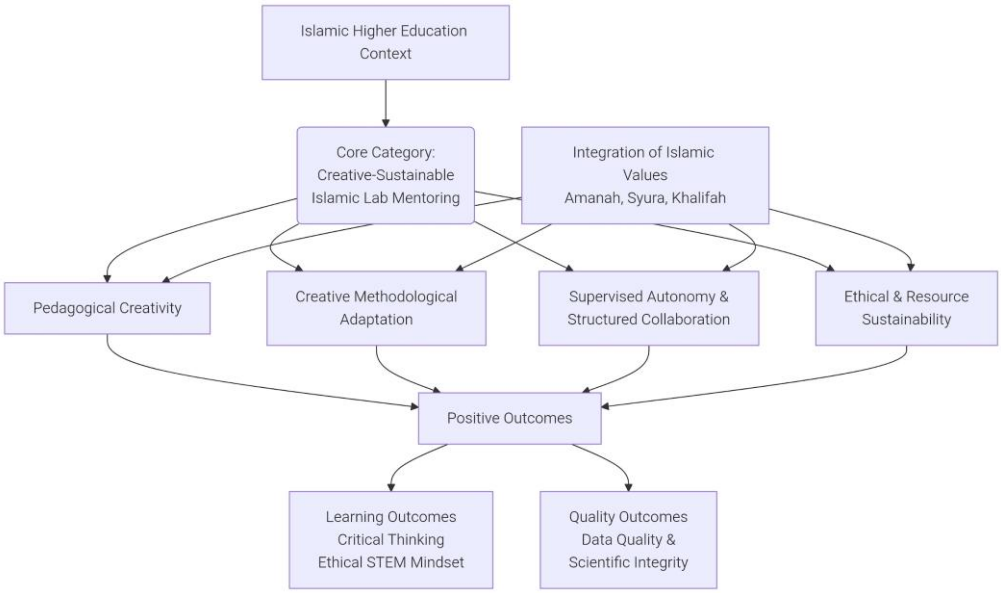


**Figure 3**. Creative-Sustainable Islamic Lab Mentoring Model

## CONCLUSION

This study concludes that biology laboratory assistants at UIN Ponorogo embody a model of "controlled creativity," in which assistants strategically integrate pedagogical scaffolding, frugal scientific adaptation, and supervised autonomy within a framework of Islamic values. This approach, grounded in *amanah* (trust), *shura* (consultation), and *khalifah* (stewardship), successfully transforms the laboratory into a space that fosters not only scientific competence but also critical thinking and ethical responsibility. The resulting model offers a sustainable and spiritually meaningful framework for science education in the context of Islamic higher education, recommending its application and further study across other disciplines.

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