APPLICATION OF IPA IN THE MANUFACTURE OF INNOVATIVE PRODUCTS: ANSWERING INDUSTRY CHALLENGES

Hikmah Mas'udah[1], Supardi[2]
[1,2] Indraprasta University PGRI

E-mail: [1)] masudahhikmah@gmail.com

Abstract

Natural Sciences (IPA) have a crucial role in encouraging innovation and increasing product competitiveness, especially in the small and medium industry (IKM) sector. This research aims to examine the application of science concepts in the process of innovation of IKM products, identify the challenges faced, and explore the potential for collaboration between academics and industry in strengthening the innovation ecosystem. The results of the study show that a number of SMEs have begun to integrate basic principles of chemistry, physics, and biology in the production process, which has an impact on improving product efficiency, quality, and sustainability. However, there are still significant obstacles, such as limited access to experts, laboratory facilities, and a lack of science-based training. These findings underscore the importance of policy support and synergy between the education sector, government, and industry to create an inclusive and sustainable science-based innovation ecosystem. With the right approach, the application of science in the SME sector can not only increase the competitiveness of local products, but also accelerate the transition to a knowledge-based economy.

Keywords: ***Natural Sciences, product innovation, small and medium industries (SMEs), academic-industry collaboration, knowledge-based economy***

1. INTRODUCTION

Natural Sciences (IPA) is one of the fields of science that has a crucial role in encouraging technological progress and innovation. In the era of the Industrial Revolution 4.0 which is marked by the rapid development of digital technology, automation, and artificial intelligence, the ability to integrate science knowledge into the production process has become a strategic necessity. The application of science is no longer limited to the academic realm alone, but has become an integral part of the product innovation process that can answer various modern industrial challenges. Science is also the foundation in developing science-based solutions that are adaptive to the changing times, including in the development of smart, efficient, and sustainable production systems (Agency for the Assessment and Application of Technology, 2020).

Changing dynamic consumer needs, energy efficiency demands, and increasing awareness of environmental sustainability require the industry to continue to innovate. It is in this context that science plays an important role, as scientific principles can be used to create products that are not only functional and aesthetically superior, but also environmentally friendly and energy-efficient. For example, the application of physics concepts allows the development of lightweight but strong materials for the transportation industry; biology is used in food biotechnology to improve product quality and durability; Meanwhile, chemistry plays a role in designing alternative raw materials that are safer and do not pollute the environment. In addition to

That, a deep understanding of environmental science, ecology, and green technology is also very important to create production processes that support the principles of sustainable development. Thus, mastery of science is not only the basic capital for the development of cutting-edge technology, but also the foundation for the creation of innovations that have a social and ecological impact. In today's world of work and industry, collaboration between scientific knowledge and practical application is a major force to create a competitive advantage and drive transformation towards a knowledge-based society (Bessant & Tidd, 2015).

However, major challenges are still faced in optimizing the role of Natural Sciences (IPA) as a driver of industrial innovation. One of the main obstacles is the limitation of synergistic collaboration between the education sector and the industrial world, which leads to a gap between the theory taught in academic institutions and the practical needs in the field. In addition, there is still a lack of applied research directed at solving concrete industrial problems, causing science research results to often only end up in scientific journals without real implementation. The lack of support for the commercialization of research results, both in the form of funding, technology incubation, and access to the market, has also weakened the contribution of IPA in producing innovative products with economic value. On the other hand, the limitation of human resources who have interdisciplinary competencies in science and entrepreneurship is also an obstacle in bridging the academic and industrial worlds (Dhewanto & Herliana, 2015).

Therefore, an in-depth and systematic study is needed on how IPA can be effectively implemented in the process of making innovative products that not only have high commercial value, but are also able to adapt to the dynamics and needs of today's industry. A transdisciplinary approach that integrates science, technology, and business aspects is essential to create a sustainable innovation ecosystem. In addition, it is also necessary to study strategies to strengthen national research and innovation policies to be more responsive to global opportunities and challenges (Fagerberg, 2005).

This study aims to identify the strategic role of science in supporting the product innovation process, describe effective application models in various industry sectors, and analyze the success factors and obstacles faced in integrating science into the production process. With this approach, the results of the research are expected to make a real contribution in encouraging the realization of synergy between educational institutions, research institutions, and the industrial world. Furthermore, this research is expected to be able to strengthen the competitiveness of local products through the development of science-based innovations that are not only technologically competitive, but also socially and ecologically relevant in facing global market challenges.

2. IMPLEMENTATION METHOD

This research uses a descriptive qualitative approach that aims to describe in depth how the application of Natural Sciences (IPA) is carried out in the process of making innovative products that answer industrial challenges. This approach was chosen because it is able to reveal the process, understanding, and experience of the research subject in a contextual and comprehensive manner. The research location is focused on several small and medium industries (SMEs) engaged in the field of appropriate technology, environmentally friendly products, or bioproducts spread across the region [mention location, for example: East Java]. The research subjects consist of industry players, product developers, technicians, and academics in the field of science who are directly involved in the innovation process. Data collection was carried out through in-depth interviews with industry players and science experts to obtain information about the process of integrating science in product innovation. In addition, direct observations are made on the production process and experiments in laboratories or production units, in order to see the practical application of the science concept. Documentation studies are also used to supplement the data, by examining technical reports, notes

research, as well as cooperation documents between industry and academics. The collected data was analyzed using thematic analysis methods with steps such as transcription, data reduction, theme categorization, and the drawing of final conclusions. The validity of the data is maintained through triangulation of sources and techniques, as well as reconfirming (member-checking) to the main source to ensure the accuracy of the data. The main instrument in this study is the researcher himself, with the help of interview guides, observation sheets, and documentation. This guide is compiled based on indicators of IPA's involvement in product innovation, such as the use of scientific concepts, the effectiveness of experiments, and the success of product implementation on an industrial scale. The implementation of the research is scheduled for three months, which includes the planning stage, data collection, analysis, and reporting of research results (Sugiyono, 2019).

3. RESULTS AND DISCUSSION

Results

Application of Natural Sciences in the Product Innovation Process

The results of the study show that small and medium industry players (SMEs) have begun to apply the basic concepts of Natural Sciences (IPA) gradually in the product innovation process, although they are not yet fully structured. Chemical concepts, for example, are used to reformulate raw materials to make them more efficient, economical, and environmentally friendly—such as the use of natural compounds as a substitute for synthetic materials that have the potential to harm health and pollute the environment. Physical principles are applied in the regulation of temperature, pressure, humidity, and energy flow during the production process, in order to improve operational efficiency and reduce production costs. This can be seen in the use of energy-efficient heating devices, controlled cooling systems, and simple automation mechanisms that utilize the laws of thermodynamics and mechanics (Ghozali, 2016).

In the food sector, the application of biological and microbiological principles is a key element in the development of products that are healthy and have a longer shelf life without having to rely on chemical preservatives. For example, the use of good microorganisms (probiotics) for natural fermentation, proper pasteurization techniques, and an understanding of enzymes and microbial metabolism in maintaining the quality of food products. Some SMEs are also beginning to understand the importance of bio-based sanitation to prevent contamination and strengthen product safety. In addition, basic knowledge about ecology and environmental impacts encourages some industry players to switch to production processes that are less wasteful and more sustainable.

These facts show that Natural Sciences are not only fundamental in the development of advanced technologies, but are also highly relevant and applicable on a small and medium-sized industrial scale. Its application is able to provide real solutions to industry challenges such as energy efficiency, product safety, and environmental sustainability. By increasing the understanding and capacity of SMEs towards applied science, the innovation process can take place faster, more directed, and more competitively. Therefore, it is important for various parties, including the government, educational institutions, and research institutions, to provide support in the form of training, technical assistance, and access to research results that can be directly implemented by the SME sector.

Effectiveness and Challenges in Science Integration in Industry

Although there are many benefits felt from the application of Natural Sciences (IPA) in the production process, the results of the study also reveal various significant challenges that still hinder the effectiveness of science integration among small and medium industry players (SMEs). One of the main challenges is the limited access to adequate laboratory facilities to conduct scientific testing, quality testing, or material analysis. This condition

causing many SMEs to have to rely on trial and error methods in the product innovation process, which is not only time-consuming and costly, but also risks producing products that are inconsistent or fail to meet market standards (Hidayat & Triana, 2019).

In addition, the low capacity of human resources in the field of science and technology is also a big obstacle. Many SMEs do not have sufficient educational or training backgrounds in the practical application of science principles. This ignorance often makes it difficult for them to understand the potential of science in solving everyday technical problems, such as energy efficiency, product stability, or waste treatment. The lack of technical training and assistance from educational institutions and research institutions exacerbates this gap, making the innovation process tend to take place independently, sporadically, and not well documented.

However, for SMEs that have been able to systematically integrate science into their production processes, the impact is very positive and significant. They show increased operational efficiency through the use of simple technologies based on physics and chemical principles, such as the use of energy-efficient processing equipment, biological waste treatment systems, and raw material conservation techniques. In addition, IPA integration also allows the creation of products with more stable quality and safe consumption, while meeting local and export market standards. Some SMEs have even begun to adopt data-driven approaches and scientific testing in production decision-making, suggesting that science integration can be a driver of sustainable industrial transformation.

Thus, although the challenges are still quite large, the positive results of the implementation of IPA in the SME sector show great potential that can be explored further. Efforts to strengthen the capacity of science in industry need to be carried out through a collaborative strategy between the government, academics, and industry players. Support in the form of integrated training, access to shared laboratories, and the development of community-based innovation centers are important steps to bridge the gap between science and industrial practice. These measures will open up wider opportunities for SMEs to optimize IPA integration and increase their competitiveness amid global economic challenges.

The Role of Academic and Industry Collaboration in Strengthening Innovation

Collaboration between academics and industry players is one of the strategic pillars in strengthening the natural sciences-based innovation process. The synergy between the theoretical excellence and research capabilities of higher education institutions with the practical needs and market dynamics faced by the industrial sector results in a strong combination in creating innovative products that are applicable and commercially valuable. A concrete example of this collaboration can be seen in the development of bioplastics from cassava waste and herbal products produced through modern extraction technology, which not only optimizes the potential of local resources, but also encourages the creation of environmentally friendly and highly competitive products. These innovations show that a collaborative approach is able to accelerate the process of technology transfer and transform research results into products that are ready to enter the market (Kotler & Keller, 2016).

Nevertheless, the reality on the ground suggests that these collaborations are still sporadic and tend to be limited to short-term projects, which often rely on grant funding or specific individual initiatives. The absence of a structured and sustainable partnership system makes the process of transferring knowledge and technology from educational institutions to industry slow and uneven. On the other hand, differences in work culture, goal orientation, and expectations between academics and business actors are often obstacles in building long-term partnerships that are mutually beneficial. For example, academics tend to

focus on the publication and development of theories, while the industry demands quick and efficient practical solutions.

Therefore, in the future, a more integrative and sustainable collaboration model is needed, such as the establishment of integrated innovation centers, campus-based business incubators, and triple helix (government-academic-industry) partnership schemes supported by clear regulations and incentives. In addition, it is also important to encourage the improvement of entrepreneurial literacy among academics, as well as applied science training for industry players in order to create effective communication in aligning the needs and potentials of each party. Through this approach, the collaboration of academia and industry is not only a supporting instrument, but also a major catalyst in strengthening the national innovation ecosystem based on science, technology, and sustainability.

The Impact of IPA-Based Innovation on Product Competitiveness

Products produced through the application of Natural Sciences (IPA) have proven to have higher competitiveness in the market, both at the local and global levels. The application of scientific principles in the production process allows the creation of products that are superior in terms of quality, efficiency, and consistency. For example, the use of natural raw materials that have gone through chemical or biological extraction processes can increase the active content in herbal products, while optimization of physical processes such as temperature and pressure regulation can extend the shelf life of food without chemical preservatives. The products produced become more stable, safe, and in accordance with health and environmental standards set by national and international regulations. Furthermore, the science-based approach also provides added value in the form of environmental sustainability and empowerment of local resources. In the context of small and medium industries (SMEs), many business actors use agricultural waste, non-timber forest products, or other local materials as alternative raw materials. With the help of simple IPA-based technology, previously worthless waste can be processed into high-value products, such as bioplastics, organic fertilizers, or natural cosmetics. This not only reduces production costs and reduces dependence on imported materials, but also strengthens local identity and increases the selling value of products in markets that are increasingly aware of sustainability issues (Rifai & Ramli, 2020).

Many SMEs admit that the science-based approach has helped them in meeting various quality certification requirements such as SNI, BPOM, or halal certificates, which are important prerequisites for penetrating modern markets, including large retail and export markets. In addition, the use of IPA in product innovation allows them to respond to consumer demands that are increasingly critical of the origin, composition, and environmental impact of the products they consume. Consumers are now not only looking for products that are functional, but also that reflect ethical values such as sustainability, safety, and social responsibility. Therefore, it can be concluded that science-based innovation has a significant impact on increasing the competitiveness of IKM products. Not only strengthens the product's position in the market, but also drives industrial transformation towards a more innovative, adaptive, and sustainability-oriented long-term approach. In order for this impact to be wider and more equitable, a national strategy is needed that supports strengthening science capacity in the industrial sector through training, technology access, and incentives for business actors oriented towards sustainable innovation.

Discussion

The application of Natural Sciences (IPA) in the product innovation process has been proven to make a significant contribution to the development of small and medium industries (SMEs), especially in improving product quality, efficiency, and sustainability. This research shows that basic concepts in the fields of chemistry, physics, and biology have begun to be used in real terms

by industry players to overcome various technical problems and answer increasingly complex market demands. The concept of chemistry is used in the formulation of more stable, safe, and environmentally friendly raw materials, such as in the manufacture of organic ingredients-based detergents or natural preservatives for food. Meanwhile, physical principles, such as heat conduction, pressure, and fluid mechanics, are utilized in the manufacturing process to improve production efficiency, save energy, and reduce waste. In the food industry, for example, the use of biological and microbiological principles has allowed SMEs to extend the shelf life of products naturally without synthetic chemicals, while maintaining nutritional value and food safety. Fermentation technology, the use of good bacterial cultures, and hygienic processing are scientific strategies that improve product quality while meeting the preferences of modern consumers who are more health-conscious. On the other hand, in the handicraft and manufacturing sectors, temperature and pressure regulation based on physics principles not only results in higher quality products, but also supports significant energy efficiency, which ultimately lowers operational costs (Setiawan & Nugroho, 2018).

These findings confirm that science is not just a theory taught in the classroom, but is a practical foundation that is very relevant in creating real solutions to today's industrial challenges. The application of science on a micro scale by SMEs shows that innovation does not always require advanced technology or large investments, but a fundamental understanding of appropriate scientific principles. Furthermore, the ability of SMEs to integrate IPA in their production process has the potential to be a competitive advantage that differentiates their products in an increasingly competitive and sustainability-oriented market. Therefore, it is important to continue to encourage training, mentoring, and dissemination of applied science to industry players, especially in the SME sector. This effort will accelerate the adoption of science in product innovation and strengthen the position of local industries as a key actor in sustainable knowledge-based economy development (Susanto, 2020).

However, the effectiveness of the implementation of science still faces challenges, especially among SMEs. The main obstacles lie in the limited access to experts, the lack of science-based technical training, and the lack of laboratory facilities that support science-based trials. As a result, many innovations carried out by industry players are only trial and error and are not based on a systematic scientific approach. Even so, several industry players who have succeeded in integrating IPA principles consistently show an increase in production efficiency and product quality. Therefore, there needs to be support from various parties so that the IPA-based innovation ecosystem can develop more widely, especially in the middle and lower industrial sector.

Furthermore, collaboration between academics and industry players is an important key in encouraging the success of science-based innovation. This study found that products such as bioplastics from cassava waste and herbal extracts from local plants can only be developed optimally through research collaboration between universities and industry players. This collaboration not only enriches the knowledge of industry players, but also encourages technology transfer from the academic world to the real sector. Unfortunately, this pattern of cooperation is still limited and has not taken place in a sustainable manner. Therefore, regulation and policy support from the government are needed to build a long-term partnership system between academia, government, and industry players as reflected in the Triple Helix model.

Finally, IPA-based innovations have proven to be able to increase the competitiveness of products in the market. Products developed through a scientific approach tend to be of higher quality, have sustainability value, and are more easily accepted by the global market that is starting to prioritize environmentally friendly products. Consumers also increasingly appreciate products that are transparent in the manufacturing process and have quality assurance. In fact, these products have

greater opportunity to obtain quality and environmental certifications which are important in the era of green industry. Thus, the integration of IPA in product development is not only a technical necessity, but also an effective business strategy in answering current and future industry challenges.

4. CONCLUSION

Based on the results of the research and discussions that have been conducted, it can be concluded that the application of Natural Sciences (IPA) in the manufacture of innovative products has an important role in improving product efficiency, quality, and competitiveness, especially in the small and medium industry (IKM) sector. The use of basic science concepts such as chemistry, physics, and biology is able to support a production process that is more environmentally friendly and oriented to modern market needs. Although there are still various obstacles, such as limited access to scientific and technological resources, industry players who successfully integrate science show superior and sustainable results. In addition, collaboration between academics and industry players has proven to be effective in producing applicable science-based innovations. Support from the government, educational institutions, and the private sector is urgently needed to build a structured and sustainable innovation ecosystem. Thus, the application of IPA is not only a solution to technical challenges in the industry, but also an important strategy in encouraging the growth of national industries that are knowledge-based, creative, and environmentally friendly.

REFERENCES

Agency for the Assessment and Application of Technology (BPPT). (2020). Application of Innovative Technology in the SME Sector. Jakarta: BPPT Press.

Bessant, J., & Tidd, J. (2015). Innovation and Entrepreneurship (3rd ed.). Wiley.

Dhewanto, W., & Herliana, S. (2015). Product and Technology Innovation in Small and Medium Industries in Indonesia. Journal of Technology Management, 14(2), 147–160.

Fagerberg, J. (2005). Innovation: A Guide to the Literature. In J. Fagerberg, D. C. Mowery, & R. R. Nelson (Eds.), The Oxford Handbook of Innovation (pp. 1–26). Oxford University Press.

Ghozali, I. (2016). Innovation Management: A Practical Approach to Improving Product Competitiveness. Semarang: Diponegoro University Press.

Hidayat, S., & Triana, E. Y. (2019). Triple Helix Collaboration in Strengthening the Innovation Capacity of Small and Medium Industries. Journal of Administrative Sciences, 16(1), 35–50.

Ministry of Industry of the Republic of Indonesia. (2021). IKM Development Strategy through Technological Innovation. Jakarta: Ministry of Industry.

Kotler, P., & Keller, K. L. (2016). Marketing Management (15th ed.). Pearson.

LIPI. (2018). Mapping the Innovation Capacity of SMEs in Indonesia. Jakarta: Indonesian Institute of Sciences.

OECD. (2017). Enhancing the Contributions of SMEs in a Global and Digitalised Economy. Paris: OECD Publishing.

Porter, M. E. (1990). The Competitive Advantage of Nations. Free Press.

Rifai, A., & Ramli, M. (2020). Application of IPA-Based Production Process Technology to Improve the Quality of MSME Products. Journal of Industrial Technology and Management, 6(1), 25–34.

Setiawan, H., & Nugroho, Y. (2018). Synergy of Academia and Industry in the Application of Science for Product Innovation. Journal of Community Service, 4(2), 101–112.

Susanto, H. (2020). Innovation and Technology in Industry 4.0. Bandung: Informatics.

World Bank. (2019). Enhancing Science, Technology, and Innovation for Industrial Competitiveness in Indonesia. Washington, DC: World Bank Group.

.