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APPLYING BUSINESS PROCESS REENGINEERING AS A CREATIVE PEDAGOGICAL METHOD IN LOGISTICS EDUCATION: A PACKAGING CASE STUDY

Paweł ŚLASKI ✉

Military University of Technology, Warsaw, Poland

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Abstract. Business Process Reengineering (BPR) is a method of introducing radical changes in the area of business processes. The concept was first presented by Michael M. Hammer in 1990 and was published in the "Harvard Business Review" journal. The method is defined as a comprehensive redesign of business processes in a company. Since the Business Process Reengineering is becoming increasingly popular both in industry and in the academic environment, the article draws attention to the use of the BPR method in students education.

The working hypothesis is as follows:
"Teamwork among students develops creativity, influences knowledge, as well as social skills and preparation for professional life."
The aim of this article is to apply the reengineering method in the education of logistics engineering students using a selected example. The article also focuses on the role of teamwork in the educational process, which develops key social skills in the Internet era.

To achieve this goal, the following research methods were used:
qualitative – reengineering, auxiliary benchmarking method, and reference modeling (mapping).
quantitative – testing of transport packaging using laboratory testers.

Process mapping enabled the development of a logistics chain proposal for packaging. Students completed the task as part of teamwork. By working together, they created an environment conducive to the development of innovative ideas.

Thanks to teamwork, which is crucial in solving problems using the reengineering method, students were able to identify a research niche, which they then analyzed in the practical part of the course in a packaging research laboratory.

Working in teams, the students learned to cooperate and, using their skills, knowledge, and experience, achieved the goal set by the lecturer. They also understood what collective responsibility for work results means.

Keywords: reengineering, creativity, laboratory tests, packaging chain.

✉ Corresponding author. E-mail: ***pawel.slaski@wat.edu.pl***

1. Introduction to reengineering – a creative method of education

Business Process Reengineering (BPR) as a method of comprehensive process transformation is perceived by researchers in the following way.

Davenport and Short (1990) described BPR as the analysis and design of workflows and business processes in organizations. Hammer and Champy, the precursors of BPR (2009), draw attention to the comprehensive redesign of business processes in order to increase the effectiveness and efficiency of the organization. Talwar (1993), focused on rethinking, restructuring and improving the business structure, processes, work methods and management.

Petrozzo and Stepper (1994), Conti and Warner (1994), Schniederjans and others (2020), Hammer and Stanton (2017), Vom Brocke and Mendling (2018) believe that BPR involves the simultaneous redesign of processes, organizations and supporting information systems in order to achieve a specific business result. Lowenthal (1994), Grint and Willcocks (1995) describing the general reconstruction of operational processes and organizational structures, focuses on the core competencies of the organization.

Problems that are solved with reengineering are usually multidimensional and complex. A creative approach can be helpful in solving these problems, because it allows you to go beyond the patterns and find unconventional and effective solutions. Creativity plays a key role in the reengineering method. Without it, this method would only be about optimizing existing problems, not creating breakthrough solutions. Creativity is therefore the driving force of creative thinking, which makes it possible to create new value for the customer and the organization.

In order for creativity to flourish in the reengineering process, appropriate conditions must be created and specific methods applied. According to the author and researchers working on this issue, it is crucial to create an interdisciplinary team that will support the generation of diverse ideas that increase openness to innovation (Biggs & Tang, 2011; Slavin, 2014). Teamwork develops the creative attitudes of members by creating conditions for the continuous enrichment of their experiences (Mazur, 2017; Okoń, 2016). Lateral thinking techniques work well in teamwork because they help to look at a problem from different points of view, which gives a chance to discover non-obvious solutions (Ślaski, 2024).

In the reengineering methodology according to Hammer and Champy (2009), an auxiliary benchmarking method can be used, e.g. according to Camp (1989) and its variation creative benchmarking.

While studying the literature, the students discovered that the issue of packaging in the supply chain (packaging) is overlooked or only briefly mentioned. Therefore, they treated this area as a research niche and decided to conduct research in this direction as a team, analyzing it in the processes of production and design of transport packaging.

Therefore, the specific goal of the project was to propose a process map that would enable the development of a new concept for the logistics chain for packaging. The students completed this task as part of a team effort, including conducting packaging strength tests in a research laboratory. Through their joint efforts, they created an environment conducive to the development of innovative ideas.

Instead of copying the best practices, it is advised to check the other industries or services to check the quality of services. The key is to see benchmarking not as a set of rules to be copied, but as a source of results and a starting point for creative thinking. Once innovative solutions have been implemented, benchmarking allows one to evaluate their effectiveness and actually deliver results. This with the possibility of a solution for further creative activities.

2. Research methodology

The article pursues educational and technical objectives. The educational objective concerns teamwork. Teamwork played a key role in the educational process in the selected case study, enabling the development of creativity among students by combining different thinking styles, experiences, and competencies. The creation of interdisciplinary research teams among students was facilitated by the fact that they are active in groups involved in applied logistics research and often solve complex logistics problems.

The research was conducted as part of the "logistics process design" course for a group of third-year students majoring in logistics with a practical profile. Due to safety conditions in the laboratory, the team could not exceed 10 people.

The Torrance Test of Creative Thinking (TTCT) was used to assess students' creativity during teamwork. It was used to evaluate their work (pre-test/post-test). The lecturer compared the students' individual work on the research task with their work on solving the same problem in a team. In their individual work, students often needed professional support from the lecturer, while teamwork only required the teacher to indicate the direction of action.

The technical objective was achieved on the basis of a case study. Students focused on issues related to packaging in supply chains. Analysis of the literature and familiarization with research methods and tools enabled students to discover a research niche in the stage of packaging research and production, which they included in the process map they developed (Figure 1). The students used the following research methods and tools in their research: reengineering according to Hammer and Champi's methodology, creative benchmarking, and reference modeling (EPC – Event Driven Process Chain). More information on creativity in student teamwork can be found in the publication: Ślaski, P. (2024). Creativity in the education of logistics students: a case study. *Creativity Studies*, *17*(2), 686–697. https://doi.org/10.3846/cs.2024.20589

3. Reengineering – case study

The case study concerns laboratory classes conducted with students with a logistics profile. Groups of students solve a problem concerning the application of the reengineering method in the packaging logistics chain. In the preparatory phase of the research, the lecturer plays the main role. He familiarizes students with the theoretical aspects of the problem under study and enables them to quickly begin their creative work. At this stage, the lecturer (teacher) explains the essence of reengineering to students, along with the methodology developed by Hammer and Champy, and discusses ways of applying this method in practice.

The methodology consists of the following stages:

1. Selection of the process for reconstruction (a choice should be made, the premises of which should be: shortcomings of the implemented processes, importance of the processes for customers, probability of obtaining significant effects in the case of reengineering).
2. Creation of a working team (a team is created to reconstruct only one process).
3. In order to understand the process, it is essential to adopt the customer's perspective and clearly identify their requirements and actual needs.
4. Process re-engineering (using the auxiliary method of benchmarking and three assumptions: rejection of established principles, application of re-engineering principles, use of new information technology).
5. Implementation of the reconstruction in practice (this can be either in its entirety or through pilot actions with attention paid to monitoring implementation in either case).

4. Course of classes

In the first and second stages of the methodology, students are divided into research teams and, together with the lecturer, define the process to be reorganized and the research objective. The aim of the research is to apply the reengineering method to optimize the packaging logistics chain and to analyze and evaluate the results of laboratory tests carried out on transport and storage packaging.

In the third stage of reengineering, students work in teams to consider what solutions the recipient (customer) of the process expects, how the process should be redesigned, and what the research niche might be. They believe that the design and laboratory testing stages of transport and storage packaging are usually overlooked or treated superficially in analyses, so they may constitute a research niche in the process.

At this stage, they define a working hypothesis and proceed to implement it in accordance with the specified methodology. The research objective requires the formulation of the following working hypothesis:

The use of reengineering to optimize the logistics packaging chain and laboratory testing of packaging improves the efficiency of supply chains, primarily at the design and production stages.

Students in research teams analyze the issue of transport and storage packaging and the role it plays in the logistics packaging chain.

Introduction to packaging issues

When reviewing the literature on packaging in supply chains, an article by Hellström and Saghir (2007) describing the Swedish retail sector is noteworthy. The potential savings from improving packaging handling in the Swedish supply chain from the retail distribution center to the point of sale are estimated at €5 million for every second saved in consumer service and retail packaging. This is an excellent reason to examine and discuss packaging, efficiency, and logistics in the supply chain.

According to Saghir Hellström and Saghir (2007), packaging is "a coordinated system for preparing goods for safe, efficient, and effective transportation, distribution, storage, retail sale, consumption, and recovery, use, or disposal, combined with maximizing sales value to the consumer and thus profit."

Packaging is an integral part of the product and the first element to protect it from external and internal influences. The universal nature of packaging lies in the fact that it can be adapted to the individual requirements of the product, while at the same time performing a number of different functions related to the specific goods (Starkowski, 2016). The proper functioning of the supply chain would not be possible without properly designed transport packaging. According to the Act of June 13, 2013, on packaging and packaging waste, transport packaging is defined as: packaging used to transport individually or collectively packaged products, preventing damage to the products, excluding containers intended for transport by road, rail, water, or air.

The definitions and concepts of packaging described above are closely related to its main functions, i.e., logistics, marketing, environmental protection, and needs throughout the product life cycle, from the first use of the packaging to the consumption of the product and disposal of the packaging material. Pfohl (2001) distinguishes between production, marketing, utility, and logistics functions, while Jansen (1991) and Jünemann (1989) divide packaging functions into primary and secondary functions. Primary functions are divided into protective and sales functions, while secondary functions include transport, storage, identification, information, and use.

Due to the nature of the research part, the rest of the article deals with the logistical functions of packaging, the most important of which relate to storage, picking, and transport processes. The storage function of packaging is related to the protection of products against mechanical damage (static and dynamic) during storage in stacks, movement in the warehouse, and delivery. Transport functions are related to the weight of the packaged goods, the dimensions and shape of the packaging, which results in the optimal use of the load capacity of the means of transport. Picking functions consist of creating assortment sets with optimal use of the load capacity of means of transport. Packaging meets logistical needs by enabling handling and distribution, as well as the delivery/transport of information about the product, conditions, and location. However, this is not a rule. Packaging is also subject to regulations and marketing requirements that influence elements such as its graphic design and format. It must both meet customer requirements throughout the supply chain and provide value to the end consumer (Korzeniowski et al., 2010).

A logistical approach to packaging issues is reflected in the consistent integration of the entire packaging chain, which aims to achieve an efficient flow of raw materials and materials with as little packaging waste as possible ending up in landfills. For this system to work effectively, it is necessary to consider not only the efficient functioning of the entire packaging chain, but also the costs incurred by each link in the chain and its environment (Kaźmierczak, 2022).

As the scale of the problems associated with packaging and product waste becomes increasingly apparent, it is crucial to design packaging systems using environmentally friendly materials and optimize them to use as little material as possible without compromising product integrity. This is crucial to achieving the waste targets set by organizations such as the United Nations, the Ellen Macarthur Foundation's Vision for a New Plastics Economy initiative, Australia's National Waste Action Plan, and Australia's 2025 National Packaging Targets. In addition to packaging waste management, one way to address the packaging waste problem is to minimize the amount of packaging used through the use of modern logistics technologies and risk management principles.

It is necessary to strike the right balance between the costs of excessive packaging and the costs associated with product damage, which is why damage parameters for different packaging scenarios must be accurate. This can be achieved by ensuring that a realistic representation of the flow of goods in the supply chain can be reproduced through laboratory simulation.

In the fourth stage, students work in teams to use the "creative benchmarking" method as the key method for solving the problem under study. To this end, they analyze the concept of an ecological supply chain. According to Srivastava (2007), this refers to the complete cycle of design, production, packaging, sale, use, and recycling, including storage, transportation, and information exchange processes, which should meet relevant environmental standards.

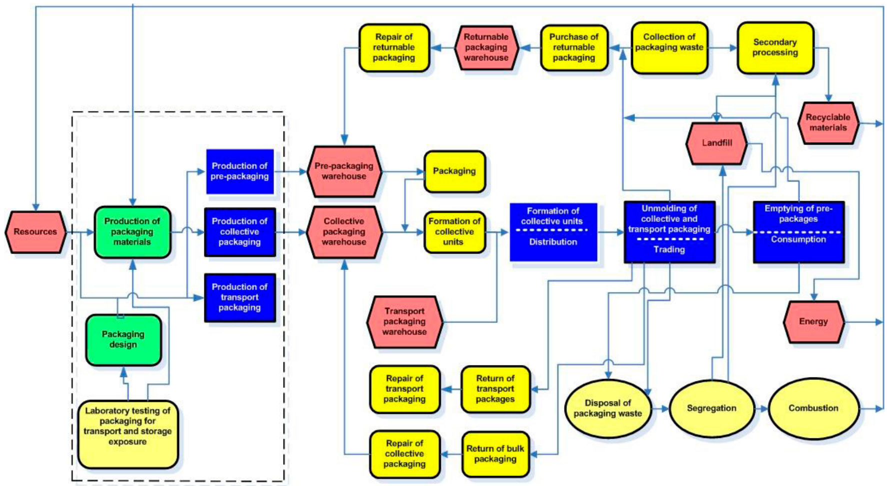

Figure 1. The logistic chain of packaging (source: student team project)

The ecological distribution process uses environmentally friendly packaging that is characterized by short decomposition times, biodegradability, or reusability. Attention is also paid to the dimensions of packaging in order to reduce transport and storage costs by optimizing the use of vehicles and storage capacity. In distribution channels, intermediaries are selected and chosen taking into account the impact of their location on the environment.

Another reference point analyzed by students at this stage is SCOR (Supply Chain Operations Reference Model), which enables the analysis and evaluation of supply chains and the identification of possible improvements in the flow of goods, resources, and information. In this way, it combines the concepts of reengineering, benchmarking, and SCOR best practices (Kasprzak, 2005).

The result of the analyses carried out in this phase is a process map in which the key activities for the process under study are identified, i.e. packaging design and testing (Figure 1).

After the analytical and evaluation part, the practical tests are carried out. Students in the same groups perform tests on testers in the packaging research laboratory, implementing the main part of the process.

Own research

- Assumptions and limitations applied to the research

The supply chain packaging research was carried out on a cardboard sample with the following dimensions: length: 650 mm, width: 230 mm, height: 540 mm, weight: 400 g/m^2, weight of the package with contents: 5 kg.

The tests were carried out in the packaging testing laboratory at an ambient temperature of 21 °C and a relative humidity of 50%.

Tester tests were carried out in accordance with the following standards:

1. PN-EN ISO 2247:2007 Packaging – Transport packaging with contents and loading units Testing of resistance to constant low frequency vibrations.
2. PN-EN ISO 12048:2002 – English version Packaging – Transport packaging with contents – Methods for testing resistance to static pressure.
3. PN-EN 22248:2001 Packaging – Transport packaging with contents – Test method for resistance to free fall impact.

▪ Study procedure

Study 1: Testing packaging for transport exposures

In most supply chains, shaking and vibrations caused by transport vehicles are considered one of the most important causes of product damage, as they are perceived as difficult to control, unlike mechanical transport. In addition, products are usually exposed to transport over a long period of time. For this reason, laboratory transport tests are often carried out to validate packaging systems to ensure that products arrive at their destination in intact condition. This is usually achieved by following the protocols set out in various standards.

Although the laboratory vibration simulation applies to all modes of transport, road transport is by far the most popular. This is mainly due to the generally higher vibrations produced by road vehicles compared to air, rail and sea transport, and the greater (and often unavoidable) reliance on road transport in most supply chains. Mechanical exposures arising from road transport are due to dynamic loads caused by vibrations of the driveline operation, changes in direction of travel and poor quality of road surfaces.

The study was carried out using two testers:

1. The shaker, which is a tester designed for laboratory simulations of typical vibration damage occurring in transport. It allows simulation of a distance of 800–1000 km in 30 minutes of operation for packages weighing up to 75 kg and with base dimensions

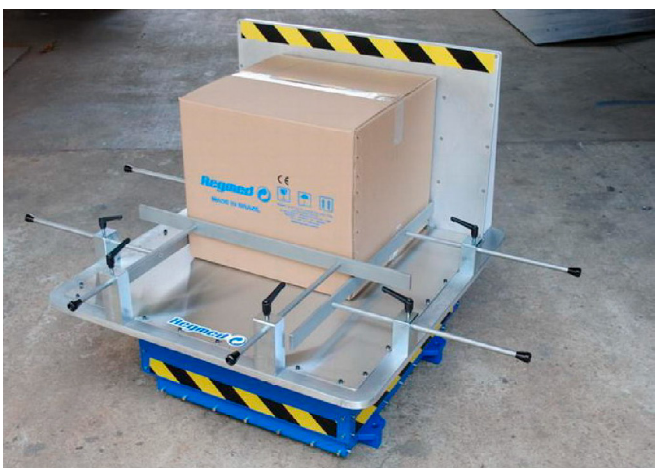

Figure 2. Laboratory shaker for testing damage to packaging with contents in the transport process (source: own development)

of up to 750 x 750 mm. The platform performs sinusoidal vibrations with an adjustable frequency of 1–5 Hz and an amplitude of 25.4 mm.

The laboratory shaker study involved placing a 5 kg sample on a vibrating table (Figure 2). After starting the tester by increasing the vibration frequency of the machine, the sample's response was observed over a period of 30 minutes using a separator rail in accordance with PN-EN ISO 2247:2007. At a frequency of 4.5 Hz, the sample was set into resonance, meaning that it was repeatedly "tossed", losing contact with the platform. The phenomenon of resonance under real conditions is an unfavourable one, as it causes shifts of the load during transport and damage to the product inside the packaging.

2. A drop tester designed to test the resistance of products and products in transport packaging to free-fall (Figure 3).

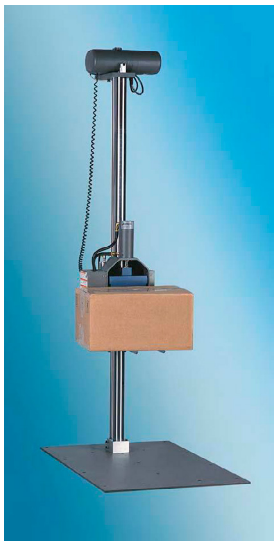

Figure 3. Free-fall tester (source: own development)

According to the study assumptions, a sample of mass m = 5 kg was used for the test, while the free-fall was performed from a height of h_0 = 1.83 m. The test was carried out in accordance with PN-EN 22248:2001. The test was carried out in accordance with PN-EN 22248:2001. The following parameters were obtained using the principle of conservation of mechanical energy:

$$E_p + E_{kmax} = const;$$

$$E_p = E_{kmax};$$

$$m \cdot g \cdot h_0 = \frac{m \cdot V^2}{2};$$

$$V_{max} = \sqrt{2 \cdot g \cdot h_0} = \sqrt{2 \cdot 9{,}81 \cdot 1{,}83} \approx 6\, m/s;$$

$$V_{max} = g \cdot t;$$

$$t = \frac{V_{max}}{g} = \frac{6}{9{,}81} = 0{,}6\ s;$$

$$E_{kmax} = \frac{m \cdot V^2}{2} = \frac{5 \cdot 36}{2} = 90\ J.$$

The values obtained from the test, especially the free-fall height h_0, the maximum velocity V_{max} and the maximum kinetic energy E_{kmax}, indicated that the packaging was not damaged and that the product inside the sample did not lose its properties.

Study 2: Testing packaging for damage during storage

Cargo damage occurring during storage is due to a variety of factors. The most important are the structural characteristics of the packaging, meaning the shape and dimensions, the weight and the distribution conditions. During handling and storage, goods are subjected to a variety of factors that can result in damage or destruction of the packaged good. Mechanical stresses in storage result from static loads; a package placed on the bottom layer of the stack is subjected to the pressure of the package on the upper layer of the stack.

The magnitude of the pressures depends on the weight of the loads in the upper layers and the stacking height. Mechanical exposures during handling depend on the handling tools used and the human factor.

The research was carried out using a universal crush tester to perform a variety of crush and compression tests on the boxes. It allows their resistance to pressure during transport and storage to be determined. The tester is designed for boxes up to 500 x 500 x 500 mm in size with a force measurement range of up to 10 kN.

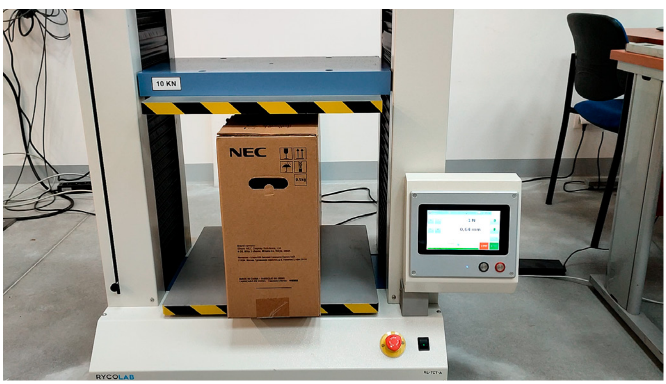

Figure 4. 10 kN crush tester (source: own development)

Two types of tests were carried out on the device (Figure 4): static and dynamic, in accordance with the PN-EN ISO 12048:2002 standard. The static test involved examining at what maximum force the packaging with its contents would break and lose its protective and logistical features. The dynamic test consisted of applying an appropriate force over a period of 12 hours and then checking whether the packaging met the requirements for continued use. The results of the dynamic test are shown in Table 1 and in the graph of tester plate displacement, maximum contact force and energy shown in Figure 5.

Attention!

The photos of testers 1–3 shown in the publication are intended, according to the author, to inspire readers to use this type of device for their own research. At the same time, the author of the article hopes that students of other technical and social sciences and humanities faculties will use the ideas contained in this publication.

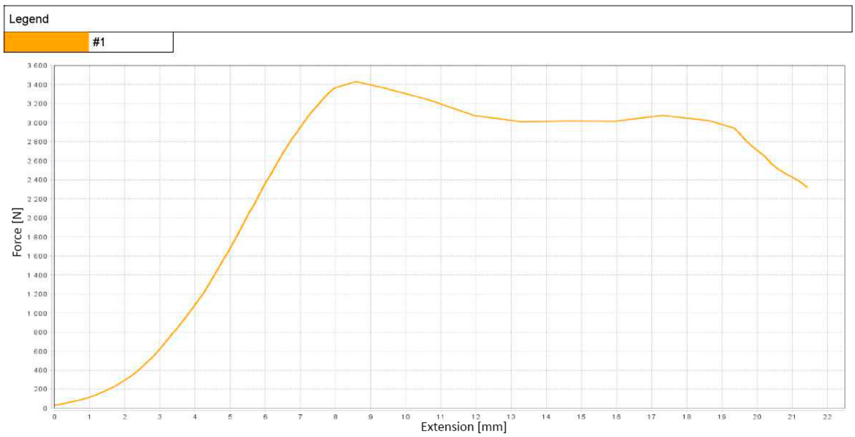

Figure 5. Graph of tester plate displacement, maximum contact force and energy (source: own development)

Figure 5 shows the test curve, with the applied forces marked on the y-axis and the test length, i.e., the displacement into the sample, marked on the x-axis. The curve in the graph indicates the maximum force at which the sample is destroyed, while the area under the curve shows the work performed by the tester on the sample.

Table 1. Dynamic test parameters of the crush tester (source: own development)

	F [N]	eF [mm]	tFmax [s]	AUC [mJ]	Fav [N]
AV	3431,000	8,588	1,750	12820,819	1492,980
MAX	3431,000	8,588	1,750	12820,819	1492,980
MIN	3431,000	8,588	1,750	12820,819	1492,980

Note: where: F – Maximum Strength; tFmax – Force Maximum Time; Fav – Medium Force / Average Force; AUC – Area Under the Curve; eF – Maximum Strength Elongation.

The Table 1 indicates that at a maximum sample force of F = 3431 [N], the packaging was damaged and lost its protective and logistical properties, but the product inside the sample was not damaged. In addition, Table 1 specifies the duration of the test, the average amount of pressure force, and the work performed by the device to destroy the sample and move it inward.

5. Discussion

The results of the laboratory research confirm the validity of the hypothesis. Goods in the supply streams of supply chains are exposed to various types of damage, mainly transport and storage damage. Attention should therefore be paid to the system of securing goods against falling and shifting on the cargo box during transport, the proper securing of goods in packaging, or the proper arrangement of packaging in stacks during storage. At the stage of designing new packaging designs, attention should also be paid to the shape, dimensions, grammage and type of material.

Students, working in groups, achieved the research goal in two stages: the analytical and evaluation stage, proposing a process map that included the key activities related to the need for laboratory tests at the design and production stages, and practical - performing tests on testers in the packaging research laboratory. At the same time, they checked how teamwork and the synergy effect that accompanies it work in the reengineering methodology (Marchisio et al., 2023).

The study did not use a control group, but an experimental group, as elements of innovative teaching (brainstorming, creative benchmarking, reference modeling) and work on a specific object of influence, i.e., students working in teams, were introduced.

Packaging research areas should be linked to technological developments and the ongoing transformation of the economy and society. The key to meeting consumer needs without over-exploiting the environment is the idea of sustainability, which is about meeting the needs of today's generation of consumers without limiting the potential to meet the needs of future generations (Hellström & Saghir, 2007). The Circular Economy model introduces principles and good practices for managing natural resources, preventing waste, increasing the level of recovery of raw materials from waste, including material and chemical recycling. The main function of the circular economy is to view waste as a valuable raw material of the industrial economy and to integrate it into the life cycle of closed-loop goods.

The premise of the Circular Economy from the point of view of packaging is to prevent waste at the design stage, to minimise material and energy consumption during production and use, and to avoid the use of substances potentially hazardous to the consumer and the environment (Australijska Organizacja Porozumienia w sprawie Opakowań Ltd., 2017). With regard to plastic packaging, it is essential to carry out recovery through material recycling in order to obtain secondary raw materials. Recycling also makes it possible to reduce the demand for petroleum-based primary materials generated at the primary raw material production stage. The implementation of these measures offers an opportunity to transform the current approach as a result of building a closed material cycle packaging economy.

6. Conclusions

Reengineering and its auxiliary method of benchmarking can be an effective tool in the process of developing creativity students. They inspire them to create innovative solutions and analyze the strengths and weaknesses of role models. Teamwork, in turn, stimulates creative thinking, which translates into improved team performance and productivity.

From the point of view of the process under study, the design of innovative packaging should provide an impetus for the development of new, intelligent, sustainable, and closed business models (Czarnecka-Komorowska, 2020). Manufacturers should offer solutions that support an ecological approach to packaging while meeting a range of requirements for quality, safety, usability, and ergonomics. The application of the eco-design concept, which allows packaging to be designed with recycling in mind, ensures that packaging sent for recycling is environmentally friendly and compatible with the available collection, sorting, and storage technology.

The author believes that the use of reengineering and the auxiliary method of creative benchmarking strengthened the students' teamwork skills, mainly thanks to the methodology (a key stage of reengineering is the selection of a team to improve the process). At the same time, teamwork supports other creative teaching methods, such as problem-based learning, lateral analysis (E. de Bono's six thinking hats), social and collaborative learning, brainstorming, and creative problem solving.

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