DESIGN-BASED RESEARCH (DBR) TO DEVELOP AN INVENTORY MANAGEMENT TOOL

PESQUISA BASEADA EM DESIGN (DBR) PARA O DESENVOLVIMENTO DE UMA FERRAMENTA PARA GESTÃO DE ESTOQUES

Maria Caroline de Araujo Souza
ORCID 0009-0006-0081-1649
Federal Institute of Education, Science and Technology of São Paulo, IFSP
Registro, Brazil
mcas.carol@gmail.com

Ronise Suzuki de Oliveira
ORCID 0000-0002-4939-0957
Federal Institute of Education, Science and Technology of São Paulo, IFSP
Registro, Brazil
ronise.suzuki@ifsp.edu.br

Meire Ramalho de Oliveira
ORCID 0000-0002-2396-1950
Federal Institute of Education, Science and Technology of São Paulo, IFSP
Capivari, Brazil
meire.oliveira@ifsp.edu.br

André Luís Tessaro
ORCID 0009-0004-8027-2651
Federal Institute of Education, Science and Technology of São Paulo, IFSP
Registro, Brazil
tessaro@ifsp.edu.br

José Roberto Herrera Cantorani
ORCID 0000-0003-1792-0383
Federal Institute of Education, Science and Technology of São Paulo, IFSP
Registro, Brazil
cantorani@ifsp.edu.br

Abstract. The educational process of teaching and learning in higher education, especially in the area of Engineering, faces a series of challenges. It is necessary to train a professional with in-depth technical knowledge, as well as communication skills, collaboration in multidisciplinary teams, problem-solving skills, and the ability to constantly learn. To this end, the use of new technologies and new educational methods becomes essential. Active learning is a student-centered approach, in which students play an active role in constructing their learning, through discussions, research, and problem-solving. To implement active learning, there are active methodologies, with which the student becomes the protagonist of their learning process. Given this context, the present study aimed to apply the Design-based Research (DBR) method to develop an inventory management tool for a small company. DBR is an approach used to develop solutions to educational problems, through the design, delivery, implementation, evaluation, and redesign of interventions in learning contexts. With this method it is possible to develop new materials, processes, tools, or technologies and, at the same time, develop the theory, test it, and evaluate the intervention. As a result of this study, the inventory management tool was built, validated, and implemented - being used to analyze different scenarios and make appropriate decisions in a small company.

Keywords: Active Methodologies; Design-based Research; DBR; Inventory Management; Small Business.

Resumo. O processo educacional de ensino e aprendizagem no ensino superior, principalmente na área de Engenharia, enfrenta uma série de desafios. É preciso formar um profissional com profundos conhecimentos técnicos, além de competências de comunicação, colaboração em equipes multidisciplinares, capacidade de resolução de problemas e capacidade de apender constantemente. Para tanto, o uso de novas tecnologias e novos métodos educativos se tornam imprescindíveis. A aprendizagem ativa é uma abordagem centrada no aluno, na qual os estudantes têm papel ativo na construção da própria aprendizagem, por meio de discussões, pesquisas e resolução de problemas. Para a concretização da aprendizagem ativa existem metodologias ativas, com as quais o estudante se torna protagonista do seu processo de aprendizagem. Diante deste contexto, o presente estudo teve como objetivo aplicar o método Design-based Research (DBR) para o desenvolvimento de uma ferramenta de gestão de estoques para uma pequena empresa. O DBR é uma abordagem utilizada para desenvolver soluções para problemas educacionais, por meio do design, realização, implementação, avaliação e redesenho de intervenções em contextos de aprendizagem. Com este método é possível desenvolver novos materiais, processos, ferramentas ou tecnologias e, ao mesmo tempo, desenvolver a teoria, testá-la e avaliar a intervenção. Como resultado deste estudo, a ferramenta para gestão de estoques foi construída, validada e implementada - sendo utilizada para analisar diferentes cenários e tomar decisões adequadas em uma pequena empresa.

Palavras-chave: Metodologias Ativas; Design-based Research; DBR; Gestão de Estoques, Pequena Empresa.

1. INTRODUCTION

Education is essential for the development of any society, underpinning economic progress, knowledge expansion, technological advancements, and improvements in the population's quality of life (Fomunyam, 2019). Higher education faces the challenge of moving beyond traditional teacher-centered practices to adopt more student-centered approaches, as conventional methods have been insufficient to equip students with the skills demanded by today's workforce (Santos & Castaman, 2023). This shift reflects the need to align university education more closely with societal expectations and the evolving professional landscape (Hartikainen et al., 2019).

Active learning and student engagement in real-world problems are crucial for university students, who benefit from experiential opportunities (Chan & Wong, 2023). In engineering education, the emergence of new operational and technological trends has created a demand for professionals with deep technical knowledge, practical communication skills, the ability to work in multidisciplinary teams, problem-solving capabilities, and a commitment to lifelong learning. Meeting these demands requires the incorporation of innovative technologies and educational methodologies (Vodovozov et al., 2021).

This transformation is also driven by Industry 4.0, where disruptive technologies reshape industries and, consequently, education. Thus, engineering programs must adopt pedagogical strategies that engage students in collaborative and student-centered activities, moving beyond traditional lectures that no longer suffice (Howell, 2021; Carneiro et al., 2020).

Active methodologies address these challenges by enabling students to learn through discovery, investigation, and problem-solving, thereby improving content retention and knowledge application (Reis et al., 2023). Among them, Design-Based Research (DBR) has shown promise in bridging theory and practice through the iterative design, implementation, and evaluation of interventions in educational contexts (Neves & Maciel, 2023; Minichiello & Caldwell, 2021).

From this perspective, it is essential that engineering students not only reflect on their learning process but also apply it to real-world problems, developing tools that meet the needs of actual organizations (Caeiro-Rodríguez et al., 2021). One such challenge is inventory management, a critical issue for micro and small businesses, where inadequate inventory control often leads to inefficiencies and financial losses (Alam, Thakur, & Islam, 2024). Bringing this issue into the academic environment offers students the opportunity to engage in active learning while creating solutions that have a social and economic impact.

Therefore, the objective of this study was to apply the Design-Based Research (DBR) methodology to develop, test, and validate an inventory management tool for a small business within the context of an undergraduate Industrial Engineering program.

DOI http://dx.doi.org/10.14571/brajets.v18.n3.823-837
ISSN 2316-9907

2. DESIGN-BASED RESEARCH FOR THE CONSTRUCTION OF TOOLS FOR INVENTORY MANAGEMENT

2.1. Active learning

Active learning represents a spectrum of pedagogical strategies centered on student engagement and participation in the learning process. This student-centered approach emphasizes the role of students in preparing for classes and developing materials, fostering a constructivist learning environment where students actively build their own knowledge (Fields et al., 2021). Active learning strategies are designed to stimulate student participation, provoke critical thinking, and bridge theoretical knowledge with real-world applications, and have been effectively applied across diverse fields such as science, technology, engineering, mathematics (STEM), and financial education (Kaiser & Menkhoff, 2022).

In an active learning framework, the learning process revolves around the student rather than the instructor. This paradigm shift encourages students to transition from passive recipients of information to active learners, cultivating skills such as creativity, autonomy, initiative, and critical thinking. In this context, instructors serve as facilitators, guiding and supporting students' learning journeys (Silva et al., 2019).

The transition from a passive to an active role in the learning process is increasingly recognized as a superior educational practice. Active learning fosters intentional learning and meaningful knowledge construction through engagement in targeted activities (Fields et al., 2021). Empirical evidence supports the effectiveness of active learning, demonstrating improvements in student performance, reductions in failure rates, and enhanced success rates, particularly in STEM disciplines (Williams & O'Dowd, 2021). Furthermore, educational institutions employing active learning strategies report producing graduates who are more competitive and better equipped to address societal challenges upon entering the workforce (Hernández-de-Menéndez & Morales-Menendez, 2019).

Active learning is operationalized through various active methodologies, which encompass a broad range of instructional strategies. Prominent among these are problem-based learning, project-based learning, peer instruction, Writing Across the Curriculum (WAC), gamification, case studies, and flipped classrooms (Hübner & Silva, 2020; Lovato et al., 2018; Santos et al., 2022). The active learning process typically begins with a preparatory phase where students engage with instructional materials such as videos and problem-solving activities prior to class. Subsequent stages involve direct interaction between students and instructors to facilitate understanding and application of concepts. Collaborative activities and diverse instructional methods enhance comprehension and expedite the learning process (Howell, 2021).

Problem-based learning, a subset of active learning methodologies, directs students to explore real-world problems and devise solutions. Design-Based Research (DBR) is a method that addresses practical issues through iterative cycles of design, implementation, evaluation, and refinement, in collaboration with researchers. DBR thus serves as an effective means of promoting active learning, particularly in engineering education, by involving students in the creation of practical solutions that benefit society.

2.2. Design-based research

Design-Based Research (DBR) is an integrated research approach that merges the strengths of both qualitative and quantitative methods, focusing on the development of applications for integration into social practices. It represents a deliberate research path aimed at exploration within educational settings (Lyons et al., 2021). DBR seeks to create theories, artifacts, and pedagogical strategies that are directly applicable and beneficial in the teaching and learning process, emphasizing problem-solving and the generation of practical solutions. These contributions range from devising innovative solutions to complex issues to enhancing theoretical understanding through the application of reusable design principles in innovative learning environments (Koivisto et al., 2018; Wolcott et al., 2019).

As a method, DBR accommodates diverse data collection strategies, offering a comprehensive view of learning in real-life contexts. Its applications extend to the development of products, processes, policies, and educational programs, thereby broadening the learning process beyond traditional classroom settings into real-world practices. This methodology proves particularly valuable for research on technological advancements that enhance learning processes (Matta et al., 2014; Sousa et al., 2023; Ørngreen, 2015).

DBR is characterized by its theoretical orientation, interventionist nature, collaborative approach, responsiveness, and iterative cycles. These features facilitate a rich, theory-supported educational design; targeted interventions in specific situations; collaborative problem-solving and validation; knowledge development through practice engagement; and continuous improvement through repeated studies and analysis (Matta et al., 2014; Wolcott et al., 2019).

Notably, DBR shares similarities with action research, with both methodologies aiming to address real-world problems through collaborative and cyclical processes (Koivisto et al., 2018; Matta et al., 2014). In the realm of engineering education, DBR is instrumental in designing processes or products, such as tools, software, or prototypes, refined through iterative interventions (Ørngreen, 2015).

The foundational principles of DBR include situating the study within a real educational context, focusing on designing and testing significant interventions, employing multiple methods for component development, conducting iterative tests and prototypes, fostering collaborative partnerships, and generating reflective design principles (Anderson & Shattuck, 2012).

DBR's methodology encompasses four main stages: problem analysis, design proposal development, iterative solution refinement and reflection for principle production, and solution implementation. This process involves defining the problem, constructing the theoretical framework and intervention proposal, executing and analyzing the intervention, and finalizing the design principles and artifact implementation (Matta et al., 2014). Despite the method's systematic appearance, it is inherently iterative, allowing for flexibility in the sequence of steps and supporting data collection from various sources, including focus groups, surveys, observations, and interviews (Crompton & Sykora, 2021).

DBR has been applied across various higher education disciplines, including pharmacy, nursing, arts and crafts, instructional material development, synchronous learning, simulation game development, and engineering, demonstrating its versatility and impact (Akdeniz & Özdinç, 2021; Dogan et al., 2021; Koivisto et al., 2018; Minichiello & Caldwell, 2021; Nortvig et al., 2020; Wolcott et al., 2019; Zydney et al., 2020).

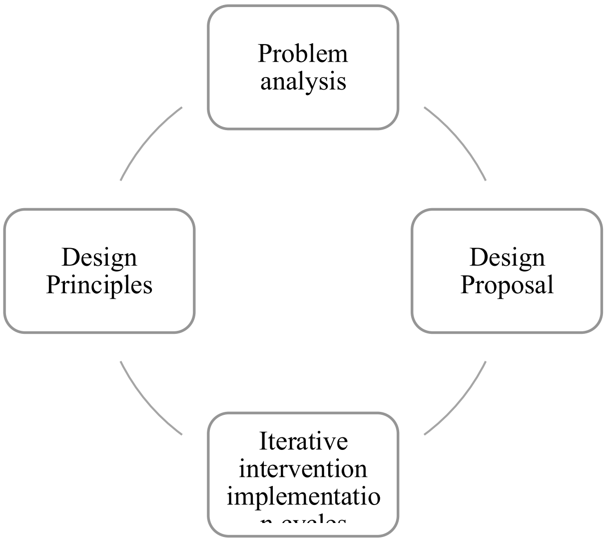

Figure 1. The DBR method. Source: Matta et al., (2014).

Based on these studies, it is possible to verify that DBR can be used to improve teaching practices, as it analyzes practical problems, develops and tests solutions, and presents the principles discovered, advancing both theoretical and practical knowledge, occurring in close collaboration between individuals (Koivisto et al., 2018). DBR is particularly relevant for Industrial Engineering education, as it can insert efficient interventions and advance understanding of how learning occurs in operations environments. Its iterative practices encourage students to build continuous and articulated research.

2.3. Product Inventory Management

Inventory management and control are pivotal elements in the decision-making processes of companies, governing the timing, quantity, and ordering of stock, as well as overseeing inventory levels, storage, and utilization of materials, semi-finished, and finished products. This multifaceted approach integrates information gathering, decision-making, monitoring, and feedback mechanisms to ensure efficient inventory oversight (Nirmala et al., 2021).In essence, inventory management bridges strategic and operational goals, aiming to enhance profitability, anticipate the implications of corporate policies on stock levels, and minimize logistics costs, while also fulfilling customer service expectations and safeguarding organizational reputation (Viktorovna & Ivanovich, 2016).

A systematic and strategic approach to inventory management ensures the optimal balance of stock quantity and quality, preventing overinvestment through judicious control of excessive or insufficient inventory levels. This balance is crucial, involving strategic decisions on investment levels and customer service, highlighting the necessity of policies and controls for monitoring and maintaining appropriate inventory levels (Biswas et al., 2017; Bonilla-Enriquez & Caballero-Morales, 2020).

However, maintaining this balance is challenging. For micro and small enterprises, these issues are even more pronounced. Limited access to organizational tools and planning methods compromises their competitive advantage, often resulting in increased costs and market vulnerability (Panigrahi; Shrivastava, & Kapur, 2024).

Common challenges faced by micro and small businesses in inventory management include maintaining incorrect inventory types or levels, overstocking or understocking, stock obsolescence, misallocated inventory, and timing issues with stock availability. These issues can disrupt operations, degrade customer service, inflate costs, and lead to customer loss. Conversely, effective inventory management can significantly reduce operational expenses and

DOI http://dx.doi.org/10.14571/brajets.v18.n3.823-837
ISSN 2316-9907

enhance the economic efficiency of these businesses (Ngubane et al., 2015; Viktorovna & Ivanovich, 2016).

Thus, inventory management emerges as a field for academic intervention, where structured methodologies can contribute to the development of practical, low-cost, and adaptable solutions. By integrating theoretical principles with the concrete needs of small businesses, it is possible to design tools that support decision-making, increase efficiency, and promote innovation. This connection between organizational challenges and pedagogical strategies justifies the adoption of the Design-Based Research (DBR) methodology, linking the educational purpose of active learning to the practical need to improve inventory management.

3. METHODOLOGY

This study employed the Design-Based Research (DBR) methodology, characterized by iterative cycles of problem identification, solution design, testing, and refinement, in real-world contexts. DBR was chosen because it allows for the simultaneous development of a practical artifact, an inventory management tool, and theoretical contributions to engineering education. The research was conducted at a small glass retail company, combining qualitative data (meetings, observations, and feedback from company staff) with quantitative data (sales history, cost estimates, and inventory parameters). This applied and interventionist approach ensured that the solution aligned with organizational needs and academic objectives.

The company faced recurring challenges, including shortages of essential inputs, accumulation of low-demand items, and a lack of structured inventory planning, which led to resource wastage and difficulty in meeting customer demand. These issues justified the adoption of DBR as a flexible and adaptable method capable of generating practical solutions through successive refinements. The methodological application involved the following steps (Figure 2): (i) understanding the research contexts and participants; (ii) survey and identification of a problem; (iii) survey of theoretical references; (iv) development of a proposal to solve the problem, based on design; (v) Iterative cycles of testing and refinements of the generated solution; (vi) reflection to produce design principles; and (vii) implementation of the solution.

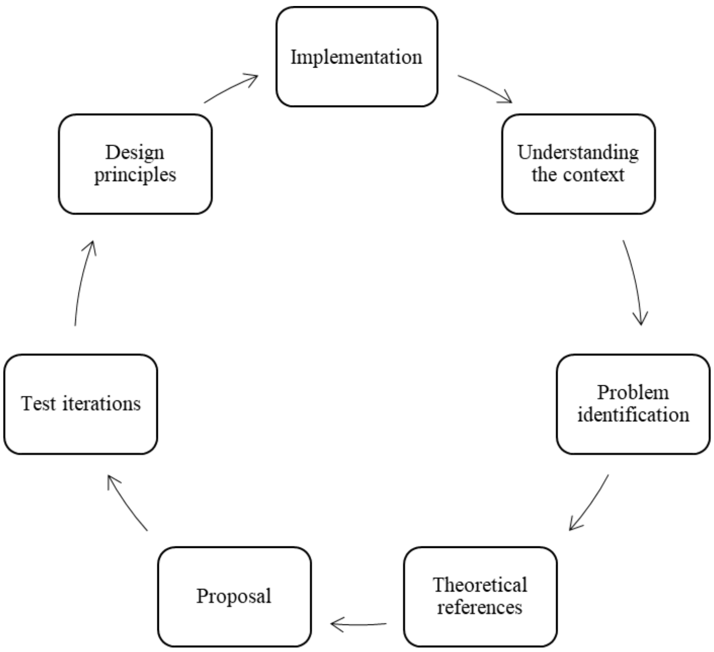

Figure 2. The DBR structure implemented in the construction of the tool.
Source: Adapted from Matta; Silva; Boaventura (2014).

DOI http://dx.doi.org/10.14571/brajets.v18.n3.823-837
ISSN 2316-9907

In the initial phase of the Design-Based Research (DBR) methodology, the research context was meticulously analyzed to comprehend the foundational parameters, topics of interest, and the dynamics of interaction and dialogue among stakeholders. This stage involved identifying the challenges faced by a small company, characterized by recurring shortages and surpluses of specific inputs, as well as a lack of strategic planning. These issues led to the immobilization of resources, missed orders, and the potential loss of clientele. Through collaborative meetings, these challenges were systematically identified and framed as a research problem. The company's participation was crucial in confirming the accuracy of the diagnosis and prioritizing the most critical issues.

Subsequently, an extensive review of the literature was conducted to establish a robust theoretical framework. This framework provided the necessary scholarly underpinning to address the identified problem, facilitating the development of a tailored solution proposal responsive to the company's specific needs. References included inventory control policies, ABC classification, and replenishment models.

The proposed solution underwent multiple iterative cycles, a process that enabled the practical application and refinement of the solution. These cycles involved comprehensive data collection and analysis, detailed process documentation, continuous refinement of the solution, and its reapplication to ensure its effectiveness and alignment with the company's operational requirements. Each cycle incorporated feedback from the company, which tested the tool in simulated scenarios, allowing for incremental improvements before final implementation.

Upon concluding these iterative cycles, the design principles and the resulting artifacts were formalized, signifying the culmination of a systematic construction process. These design principles represent bespoke solutions, rigorously developed and empirically validated, that the company could implement to address its identified challenges.

The final step involved presenting, testing, and validating the developed tool within the organization. This phase also involved incorporating feedback and suggestions, further enhancing the tool's utility and effectiveness.

This comprehensive approach, emblematic of the DBR methodology, underscores the importance of a collaborative, iterative process in developing and refining solutions that are both practical and theoretically grounded, offering significant contributions to both the participating organization and the broader academic community.

4. RESULTS

4.1 The application of Design-based research

In the initial phase of the research, a comprehensive understanding of the company's context revealed significant challenges in inventory management, characterized by discrepancies in stock levels. Specifically, there were instances of excessive quantities of certain items, while recurrent shortages of other inputs were noted. This situation arose from the absence of a systematic approach to purchasing decisions, which were made arbitrarily, leading to imbalances in inventory levels.

During the problem identification phase, critical issues impacting demand fulfillment were pinpointed. These included the frequent unavailability of specific inputs, excessive stock levels for certain products, and the resultant capital immobilization. Through collaborative efforts, a pivotal research question was formulated: How can inventory management be optimized to accurately determine order quantities, timing, and selection of items for resale within the glass industry?

The literature review phase explored several key areas, including inventory categorization, management strategies, replenishment techniques, system performance evaluation, the ABC

DOI http://dx.doi.org/10.14571/brajets.v18.n3.823-837
ISSN 2316-9907

analysis, economic order quantity (EOQ) calculations, service level indicators in inventory management, and the application of Python programming for tool development. By integrating concepts such as the ABC classification and EOQ models into a practical tool, the study exemplifies the potential of DBR to connect theoretical principles with everyday managerial needs, thereby reinforcing the dual role of DBR in refining theory and producing artifacts of real-world utility (Anderson & Shattuck, 2012).

In the stage of proposal development, a strategy was outlined to classify inventory items according to their significance using the ABC analysis. This approach facilitated the determination of critical parameters and the selection of an optimal replenishment methodology. Consequently, a specialized inventory management tool was created, followed by the examination of various operational scenarios.

The testing and iteration phase involved multiple cycles of evaluation and enhancement based on feedback from the company. This iterative process led to the identification of areas for improvement, culminating in the refinement of the tool. Subsequent rounds of evaluation and adjustment continued until a final version of the tool was established. The iterative cycles demonstrated the importance of feedback from stakeholders, confirming the collaborative essence of DBR. As an active methodology, this iterative process promoted autonomy, problem-solving, and negotiation skills, bringing a series of pedagogical benefits (Reis et al., 2023).

The outcome of this process was the development of a bespoke inventory management tool, tailored to address the specific challenges identified in the company. The sequential steps undertaken in the construction of this tool are concisely documented in Table 1, illustrating the application of the Design-Based Research (DBR) methodology to solve a practical inventory management problem.

Table 1. DBR to develop an inventory management tool

Stage	Description
Understanding the research context	The company dealt with an imbalance of purchased inputs, living with excess and shortage.
Problem identification	Failure to comply with the demand; lack of inputs or high inventory level.
Identification of the research question	How do you manage inventory, considering how much, when, and which items to order for resale in the glass industry?
Survey of theoretical references	Types of inventory; inventory management; resupply methods; system performance measures; ABC curve; economic lot size (ELS); service level indicators in inventory management and Python language to build the tool.
Development of a proposal	Proposal containing: classification of items, using the ABC curve; identification of the most important items; the identification of parameters; definition of the resupply method and scenario analysis.
Iterative testing cycles	The adopted parameters were constantly modified until a feasible solution was reached.
Reflection and design principles	The customized solution was developed.

Source: Own authorship (2024)

4.2 Construction of the inventory management tool

The tool was developed with the Periodic Review Replenishment Method. For the company, inventory management through periodic review ensures that the order point can be determined at constant intervals, facilitating the operational purchasing process. Another reason is that you do not need to monitor the quantity of inventory from moment to moment

DOI http://dx.doi.org/10.14571/brajets.v18.n3.823-837
ISSN 2316-9907

until you reach the point where the inventory reaches the quantity stipulated for the purchase request.

The solution used the following variables: service level, annual inventory maintenance cost, lead time, and cost per order, as seen in Table 2.

Table2. Summaries of the parameters to be used in the calculations

Parameter	Determined value
Service level	95% = 1,645
Annual maintenance cost	40%
Lead Time	15 days = 0,5 months
Ordering costs	R$24,00

Source: Own authorship (2024)

The ordering cost involves the structure necessary for the supply to work (quotation, purchasing, complaints, receipt, inspection, movement of materials, and payments). This is the cost of preparing and monitoring each order (Fernandes & Godinho Filho, 2010). The company did not calculate this cost. In this way, the cost of ordering was estimated based only on the workload carried out by a company employee to carry out the processes involving the activities of checking and checking items in inventory, requesting and monitoring the purchase, receipt, inspection, and checking items, in addition to separating items for customer orders. In this way, it was estimated that around 180 minutes are used to complete each order, converted into reals based on the value of the hour the employee (intern) worked, resulting in R$24.00. It is understood that this value would be the minimum order cost to be adopted, that it is underestimated, and that it can be improved.

The inventory holding fee includes the cost of obsolescence, the opportunity cost, and the cost of maintaining inventory (space rental, materials handling, and insurance, among others). In Brazil, this rate varies between 30% and 50% of total costs (Fernandes & Godinho Filho, 2010). Likewise, the company did not calculate this cost. It was decided to use an average inventory maintenance rate derived from the literature; that is, a rate of 40% was adopted, an average between reference values (30% to 50%). It is about adopting an estimate; it is not the actual value, and therefore, this value may be undersized and can be better adjusted by the company.

The lead time is the period that elapses between the company placing the order and receiving the goods (Fernandes & Godinho Filho, 2010). In this case, the lead time is 15 days, obtained according to the supplier's latest deliveries. The service level is an indicator of how the product is available. A service level of 95% was used; that is, it represents the probability of having this product in inventory.

The parameters in Table 1 were used to construct the scenarios and define the lot size. The inventory of accessory items for resale were analyzed using the ABC Curve (Figure 3), and then the importance of the groups was defined. The spreadsheet contains cells filled with a white background, which can be changed, and cells with a gray background, which indicate parameters or contain calculations. These are the cells that are blocked for editing.

DOI http://dx.doi.org/10.14571/brajets.v18.n3.823-837
ISSN 2316-9907

Priority Items				
Group	43 | Glass hardware			
Product	Description	R$	% item	%accumulated
1007	AL 1114 Dobradiça Automática p/ Box AL Puxadores Branco	1,2	0,028	0,027707227
1700	AL 1302 Suporte de Canto AL Puxadores Branco	1	0,023	0,050796583
2158	AL 1329 Suporte de Centro AL Puxadores Branco	1,5	0,035	0,085430616
2202	AL 1335 Trinco - Ferragem AL AL Puxadores Branco	5	0,115	0,200877396
3001	AL 1519 Trinco Inferior AL Puxadores Branco	2,3	0,053	0,253982914
3407	AL 1531 Contra Fechadura Central C/ Aba AL Puxadores Branco	2,5	0,058	0,311706303
3773	AL 3210 Fechadura para porta de abrir com furo AL Puxadores Alumínio Branco	1,5	0,035	0,346340337
5715	KIT 01 - Ferragem AL AL Puxadores Branco	1,6	0,037	0,383283306
5753	KIT 02 - Ferragem AL AL Puxadores Branco	1,3	0,03	0,413299469
5784	KIT 02 - Ferragem AL AL Puxadores Preto	1,27	0,029	0,442622951
5791	KIT 03 - Ferragem AL AL Puxadores Branco	1,82	0,042	0,484645578
5838	KIT 04 - Ferragem AL AL Puxadores Branco	1,95	0,045	0,529669822
5913	KIT 06 - Ferragem AL AL Puxadores Branco	1,78	0,041	0,570768876
5944	KIT 06 - Ferragem AL AL Puxadores Preto	1,89	0,044	0,614407758
18616	KIT 07 - Ferragem AL AL Puxadores Branco	1,2	0,028	0,642114985
18838	AL 1570 Fecho Central Vidro / Vidro - Bate fecha AL Puxadores Branco	0,8	0,018	0,66058647
18876	AL 1571 Fecho Lateral Vidro / Alvenaria - Bate-fecha AL Puxadores Branco	0,9	0,021	0,68136689
18913	AL 1571 Fecho Lateral Vidro / Alvenaria - Bate-fecha AL Puxadores Preto	0,95	0,022	0,703301778

Figure 3. ABC Curve of Resale Products. Source: Own authorship (2024)

The ABC curve allowed the company to analyze the priority of items used as raw materials. Not all inputs have the same importance within a manufacturing process. Classifying items and allowing different levels of control based on their importance allows us to concentrate efforts on those that will bring better results for the company.

The choice of Microsoft Excel as a platform demonstrates the potential for accessible and low-cost technologies to drive management improvements. This result is significant for small businesses that lack ERP systems but still require decision-making support resources. Furthermore, the tool's adaptability demonstrates pedagogical relevance, as it can be applied in other educational contexts to teach inventory management practically and effectively.

The tool was developed using Microsoft Excel software. The company chose this software because it is low-cost, and its employees are already familiar with it (Figure 4).

After defining the priority items and selected parameters, the tool could also direct the purchase batch.

Once the information is updated, the values of interest, such as safety inventory, maximum demand, and purchase lot, continue to be updated automatically (Figure 4). The physical inventory column is a field that must be updated whenever it is necessary to request a new purchase batch (Figure 4). The parameter field is also available for editing (Figure 4) so that information on service level, supplier delivery time (lead time), and ordering and annual inventory maintenance costs can and should be reviewed periodically.

INVENTORY MANAGEMENT AND CONTROL
Standard deviation considering the 12 months (T = 15 days)
Periodic Review System for Inventory

Parameter		
Service Level:	95%	1,645
Lead Time:	0,5	month (15 days)
Ordering cost:	R$ 24,00	
Annual maintenance cost:	40%	

			January/ 2021	February/ 2021	March/ 2021	April/ 2021	May/ 2021	June/ 2021	July/ 2021	August/ 2021	September / 2021	October/ 2021	November/ 2021	December/ 2021		
			01/01 a 31/01	01/02 e 28/02	01/03 e 31/03	01/04 e 30/04	01/05 e 31/05	01/06 e 30/06	01/07 e 31/07	01/08 a 31/08	01/09 a 30/09	01/10 a 31/10	01/11 a 30/11	01/12 a 31/12		
Group	Product	Description	Amount	Amount	Amount	Amount	Amount	Amount	Amount	Amount	Amount	Amount	Amount	Amount	Inventory	Q (purchase lot)
Group 01	17 | Kit Box															
0	F1BC1500	Kit Frontal (1 FX + 1 C(	3	5	5	3	8	4	9	11					0	11
1	F1BC1200	Kit Frontal (1 FX + 1 C(	7	3	4	6	4	0	15	12					6	8
2	F1BC1330	Kit Frontal (1 FX + 1 C(	2	6	16	2	7	4	10	9					5	10
3	C1BC1000	Kit Canto AL Puxadore	1	1	4	2	2	4	4	1					1	3
4	F1BC1800	Kit Frontal (1 FX + 1 C(	2	2	0	1	1	4	0	1					0	3

Figure 4. Inventory Management Tool. Source: Own authorship (2024)

DOI http://dx.doi.org/10.14571/brajets.v18.n3.823-837
ISSN 2316-9907

After inserting historical data into the tool, it was decided to build scenarios to identify different analysis perspectives for the company. Therefore, the scenario analysis considered three possibilities:

- Scenario 1: 12 months of sales analysis, calculation of the ELS, and the ideal replenishment time for each item;
- Scenario 2: 6 months of sales analysis, ELS calculation, and fixed resupply time of 15 days;
- Scenario 3: 12 months of sales analysis, calculation of ELS, and fixed resupply time of 15 days.

A fixed resupply time of 15 days was considered in two scenarios, because the company generally uses 15 days to make the necessary purchases and, therefore, in the company's interest, the standard was maintained.

Scenario 1 generally presented larger quantities for the purchase order, with resupply intervals varying from one to seven months. In this case, inventory costs would be higher, considering that 634 units of item 4 of group 3 would have to be managed, for example, which are small pieces – around 3 x 3 cm – and would still require more storage space. However, ordering costs would be reduced, with longer and varied ordering intervals for each item.

Therefore, scenario 2 presented lower purchase quantities than scenario 3 overall. In both cases, the organization would be comfortable maintaining its purchasing routine with the supplier and must manage the quantities requested.

Another aspect that needs to be highlighted is the cost of transportation, which should also be used as a guide for this decision-making. In a brief analysis of the twelve months evaluated in the study, it was found, in consultation with financial records, that the company had an average monthly transportation cost of approximately R$1,000.00, totaling R$12,000.00 in one year. As there was no safety inventory for the items, orders would appear for products where the inputs were not available in inventory, and, in an attempt to meet customer demand as quickly as possible, the company ended up requesting orders in these cases as well, not carefully following the fifteen-day intervals between one request and another.

Peinado & Graeml (2007) state that the price applied for smaller loads is significantly similar to orders with larger quantities up to a specific limit. Therefore, considering the implementation of the proposed scenarios, transportation costs could be reduced if the company adopted a resupply interval of fifteen days or an even more significant amount if it adopted the scenario with a calculated resupply interval. This reduction would occur by reducing the amount of freight to be requested. Scenario analysis highlights the trade-offs between inventory and ordering costs, providing educational insights that reinforce critical thinking, essential for engineering education.

The results obtained in this study are similar to those achieved in other higher education institutions. For example, Caeiro-Rodríguez et al. (2021) reported on European engineering programs that used active methodologies to develop technical and soft skills. Crompton and Sykora (2021) demonstrated how DBR can guide the development of educational technologies through iterative and collaborative cycles. Koivisto et al. (2018) provided empirical evidence of active learning practices that improved student performance and engagement. y aligning with these exemplary cases, the present research reinforces the dual role of DBR in producing practical solutions for organizations and pedagogical advances for engineering education.

Beyond the business benefits, there are broader implications for education and professional practice. From an educational perspective, DBR can transform real-world problems into learning opportunities by strengthening students' critical thinking, negotiation skills, and decision-making abilities. Using an accessible tool like Microsoft Excel reinforces the use of low-cost technologies as teaching resources. From a professional perspective, the tool offers small businesses an affordable alternative for inventory management, supporting informed decision-making and mitigating operational risks. Finally, the integration between the educational institution and the company highlights the potential for knowledge transfer, innovation, and social impact.

5. CONCLUSION

The primary objective of this study was to apply the Design-Based Research (DBR) methodology to the development of an inventory management tool for a small company, within the context of an undergraduate Industrial Engineering course. The results demonstrate that DBR can effectively bridge theory and practice, enabling students to address real organizational problems while consolidating their academic learning.

DBR, traditionally employed in educational solution development, met its goals by fostering the design and creation of a product that addresses a genuine societal issue. This methodology encouraged students to engage in active learning strategies, empowering them to solve real-world problems and become central to their educational journey. Consequently, the tool was constructed, validated, and implemented, enabling the analysis of various scenarios to inform decision-making processes within a small enterprise.

The developed tool proved helpful for the company, offering a low-cost alternative to improve inventory management processes. The experience also represented a valuable opportunity to integrate theoretical knowledge with practical application, reinforcing essential skills such as problem-solving, decision-making, and effective communication.

The application of DBR stages in practice identified the most suitable replenishment method for the company under its current operational conditions, namely, the periodic review method. This method facilitated the calculation of safety inventory levels, replenishment timings, and purchase quantities. Three scenarios were evaluated for analysis: the first scenario applied a calculated replenishment time, while the other two aligned more closely with the company's existing practices, which involve fixed replenishment intervals for all items and a preference for smaller order quantities. Scenario 1, which utilized the calculated replenishment time, resulted in larger order quantities, posing challenges related to financial investment and storage capacity. Scenarios 2 and 3, which were more familiar to the company, required adjustments to accommodate new quantities, as the existing policy did not account for safety inventory.

Under any of the proposed scenarios, it was anticipated that company employees would experience enhanced decision-making efficiency in inventory management. However, the continued efficacy of the developed spreadsheet tool necessitates regular updates with sales data from subsequent months to ensure calculations remain current.

The tool improved the company's decision-making capabilities and resource optimization. Given the challenges inherent to small enterprises, adequate resource allocation and process optimization can lead to substantial improvements. Proper inventory management ensures accurate control of materials, process efficiencies, customer satisfaction, and cost reductions, all of which are crucial in dynamic market conditions where every enhancement can bolster competitiveness and viability.

The study highlights the importance of active methodologies in engineering education, those that promote interaction with the business environment. Success stories and exemplary practices from other educational institutions can be considered to enrich teaching and learning in engineering programs.

Initiatives of this nature promote integration between academia and industry, with benefits for both students and companies. Future work should also explore partnerships with companies and organizations in the sector, offering real-world cases for application and contributing to the creation of more dynamic, inclusive, and efficient educational environments.

The study encountered specific limitations, particularly regarding the precise breakdown of organizational costs. The lack of established values for inventory holding fees and ordering costs necessitated estimations, which likely led to inaccuracies. Accurate cost assessments tailored to each company's reality are essential. Additionally, the sustainability of the proposed method requires manual updates to the spreadsheet with new data, as automatic updates available in software systems are not feasible.

Future research should more accurately quantify inventory-related costs and explore the financial implications of implementing the developed tool, offering a basis for comparison with subsequent studies.

REFERENCES

Akdeniz, M., & Özdinç, F. (2021). Maya: An artificial intelligence based smart toy for pre-school children. *International Journal of Child-Computer Interaction*, *29*, 100347.

Alam, M. K., Thakur, O. A., & Islam, F. T. (2024). Inventory management systems of small and medium enterprises in Bangladesh. *Rajagiri management journal*, *18*(1), 8-19.

Anderson, T., & Shattuck, J. (2012). Design-based research: A decade of progress in education research?. *Educational researcher*, *41*(1), 16-25.

Biswas, S. K., Karmaker, C. L., Islam, A., Hossain, N., & Ahmed, S. (2017). Analysis of different inventory control techniques: a case study in a retail shop. *Journal of Supply Chain Management Systems*, *6*(3), 35.

Bonilla-Enriquez, G., & Caballero-Morales, S. O. (2020). Simulation model for assessment of non deterministic inventory control techniques. *Asian Journal of Research in Computer Science*, *5*(3), 63-70.

Caeiro-Rodríguez, M., Manso-Vázquez, M., Mikic-Fonte, F. A., Llamas-Nistal, M., Fernández-Iglesias, M. J., Tsalapatas, H., ... & Sørensen, L. T. (2021). Teaching soft skills in engineering education: An European perspective. *Ieee Access*, *9*, 29222-29242.

Carneiro, S. M. G., de Araujo Sousa, P. S., & Alvarenga, E. M. (2020). Bioensaio como Método de Aprendizagem Aliado à Teoria em Biologia no Ensino Médio. *Revista Eletrônica Sala de Aula em Foco*, *9*(1), 144-157.

Chan, C. K., & Wong, H. Y. (2023). Students' perception of written, audio, video and face-to-face reflective approaches for holistic competency development. *Active Learning in Higher Education*, *24*(3), 239-256.

Cordeiro, L. G., Picinin, C., Lievore, C., & Klafke, R. (2022). Metodologias Ativas de Ensino Aplicadas às Engenharias nas World-Class Universities. *Cadernos de Educação Tecnologia e Sociedade*, *15*(4), 455-466.

Crompton, H., & Sykora, C. (2021). Developing instructional technology standards for educators: A design-based research study. *Computers and Education Open*, *2*, 100044.

Dogan, E. I. K., Terragni, L., & Raustøl, A. (2021). Student nurses' experience of learning about the right to food: Situated professional development within clinical placement. *Nurse education today*, *98*, 104692.

Fernandes, F. C. F., & Godinho Filho, M. (2010). Planejamento e controle da produção: dos fundamentos ao essencial.

Fields, L., Trostian, B., Moroney, T., & Dean, B. A. (2021). Active learning pedagogy transformation: A whole-of-school approach to person-centred teaching and nursing graduates. *Nurse Education in Practice*, *53*, 103051.

Fomunyam, K. G. (2019). Education and the Fourth Industrial Revolution: Challenges and possibilities for engineering education. *International Journal of Mechanical Engineering and Technology*, *10*(8), 271-284.

DOI http://dx.doi.org/10.14571/brajets.v18.n3.823-837
ISSN 2316-9907

Hartikainen, S., Rintala, H., Pylväs, L., & Nokelainen, P. (2019). The concept of active learning and the measurement of learning outcomes: A review of research in engineering higher education. *Education Sciences*, *9*(4), 276.

Hernandez-de-Menendez, M., & Morales-Menendez, R. (2019). Technological innovations and practices in engineering education: a review. *International Journal on Interactive Design and Manufacturing (IJIDeM)*, *13*, 713-728.

Howell, R. A. (2021). Engaging students in education for sustainable development: The benefits of active learning, reflective practices and flipped classroom pedagogies. *Journal of Cleaner Production*, *325*, 129318.

Hubner, M. L. F., & Silva, J. F. M. D. Active methodologies and the new perspectives of the cataloguing teaching in the librarianship courses. *Informação & Informação; v. 25, n. 3 (2020); 52-86*, *24*(2), 86-52.

Kaiser, T., & Menkhoff, L. (2022). Active learning improves financial education: Experimental evidence from Uganda. *Journal of Development Economics*, *157*, 102870.

Koivisto, J. M., Hannula, L., Bøje, R. B., Prescott, S., Bland, A., Rekola, L., & Haho, P. (2018). Design-based research in designing the model for educating simulation facilitators. *Nurse Education in Practice*, *29*, 206-211.

Lovato, F. L., Michelotti, A., & da Silva Loreto, E. L. (2018). Metodologias ativas de aprendizagem: uma breve revisão. *Acta Scientiae*, *20*(2).

Lyons, K. M., Lobczowski, N. G., Greene, J. A., Whitley, J., & McLaughlin, J. E. (2021). Using a design-based research approach to develop and study a web-based tool to support collaborative learning. *Computers & Education*, *161*, 104064.

Matta, A. E. R., Silva, F. D. P. S. D., & Boaventura, E. M. (2014). Design-based research ou pesquisa de desenvolvimento: metodologia para pesquisa aplicada de inovação em educação do século XXI. *Revista da FAEEBA: educação e contemporaneidade*, *23*(42), 23-36.

Mello, R. M. S., & Cavalcanti, M. F. R. (2020). Desenvolvimento de competências e metodologias ativas: a percepção dos estudantes de graduação em administração. *Administração: Ensino e Pesquisa*, *21*(1), 52-91.

Minichiello, A., & Caldwell, L. (2021). A narrative review of design-based research in engineering education: Opportunities and challenges. *Studies in Engineering Education*, *1*(2).

Neves, J. A., & Maciel, A. M. M. (2023). A formação dos planetas do sistema solar: a construção de uma sequência de ensino e aprendizagem. *Revista Eletrônica Debates em Educação Científica e Tecnológica*, *13*(1).

Ngubane, N., Mayekiso, S., Sikota, S., Fitshane, S., Matsoso, M., & Bruwer, J. P. (2015). Inventory management systems used by manufacturing small medium and micro enterprises in Cape Town.

Nirmala, D. A. R., Kannan, V., Thanalakshmi, M., Gnanaraj, S. J. P., & Appadurai, M. (2022). Inventory management and control system using ABC and VED analysis. *Materials Today: Proceedings*, *60*, 922-925.

Nortvig, A. M., Petersen, A. K., Helsinghof, H., & Brænder, B. (2020). Digital expansions of physical learning spaces in practice-based subjects-blended learning in Art and Craft & Design in teacher education. *Computers & Education*, *159*, 104020.

Ørngreen, R. (2015). Reflections on design-based research: in online educational and competence development projects. In *Human Work Interaction Design. Work Analysis and Interaction Design Methods for Pervasive and Smart Workplaces: 4th IFIP 13.6 Working Conference, HWID 2015, London, UK, June 25-26, 2015, Revised Selected Papers 4* (pp. 20-38). Springer International Publishing.

Reis, A., Alves, A., & Wendland, E. C. (2023). Metodologias ativas no ensino superior: um mapeamento sistemático no contexto dos cursos de engenharia. *Educação em Revista*, *39*, e39012.

Santos, D. F. A., & Castaman, A. S. (2023). Metodologia ativa no ensino superior: um estudo sobre as dificuldades de implementação do método. *Revista Eletrônica Debates em Educação Científica e Tecnológica*, *13*(1).

Silva, J. B. D., Sales, G. L., & Castro, J. B. D. (2019). Gamificação como estratégia de aprendizagem ativa no ensino de Física. *Revista Brasileira de Ensino de Física*, *41*.

Silva, P. C., & Teixeira, R. (2023). O Perfil do Egresso da Engenharia Ambiental: Perspectivas e Apontamentos para a Implementação de Metodologias Ativas em Educação em Engenharia. *Cadernos de Educação Tecnologia e Sociedade*, *16*(2), 194-209.

Sousa, E. E. L., Cruz, E., & Costa, F. A. (2023). Um Percurso Metodológico para a Construção de um Dispositivo de Apoio ao Desenvolvimento e Avaliação de Competências Digitais no 1. º Ciclo do Ensino Básico. *Cadernos de Educação Tecnologia e Sociedade*, *16*(se1), 41-54.

Teerasoponpong, S., & Sopadang, A. (2022). Decision support system for adaptive sourcing and inventory management in small-and medium-sized enterprises. *Robotics and Computer-Integrated Manufacturing*, *73*, 102226.

Tracey, M. W., & Hutchinson, A. (2018). Reflection and professional identity development in design education. *International Journal of Technology and Design Education*, *28*, 263-285.

Viktorovna, I. B., & Ivanovich, P. P. (2016). Issues of forming inventory management system in small businesses. *International Review of Management and Marketing*, *6*(3), 522-527.

Vodovozov, V., Raud, Z., & Petlenkov, E. (2021). Challenges of active learning in a view of integrated engineering education. *Education Sciences*, *11*(2), 43.

Zydney, J. M., Warner, Z., & Angelone, L. (2020). Learning through experience: Using design based research to redesign protocols for blended synchronous learning environments. *Computers & Education*, *143*, 103678.

Williams, A. E., & O'Dowd, D. K. (2021). Seven practical strategies to add active learning to a science lecture. *Neuroscience Letters*, *743*, 135317.

Wolcott, M. D., Lobczowski, N. G., Lyons, K., & McLaughlin, J. E. (2019). Design-based research: Connecting theory and practice in pharmacy educational intervention research. *Currents in Pharmacy Teaching and Learning*, *11*(3), 309-318.

DOI http://dx.doi.org/10.14571/brajets.v18.n3.823-837
ISSN 2316-9907