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THE ROLE OF ARTIFICIAL INTELLIGENCE IN DEVELOPING PACKAGING DESIGNS AND ENHANCING CONSUMER EXPERIENCE APPLICATION TO STUDENTS OF THE PRINTED PACKAGING DESIGN COURSE

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ABSTRACT

Packaging design is a fundamental element in modern marketing strategies, playing a crucial role in attracting consumers and enhancing their experience by combining aesthetic and functional aspects. With rapid technological advancements, artificial intelligence (AI) has become a vital tool in improving designs by analyzing vast amounts of data and identifying consumer behavioral patterns. This enables designers, particularly students specializing in print packaging design, to make data-driven design decisions that contribute to developing innovative packaging solutions that meet evolving market demands. The application of AI technologies in packaging design extends beyond enhancing visual aspects to improving production efficiency and reducing costs through automation and future demand forecasting. AI also supports sustainability efforts by helping companies select eco-friendly materials, optimize packaging sizes, and minimize waste, which is increasingly important in meeting both regulatory requirements and consumer expectations for environmentally responsible products. Therefore, this research highlights the importance of exploring how AI can be utilized to advance packaging designs and its impact on consumer experience and the educational process for packaging design students. By examining both industry applications and academic implications, the study demonstrates that AI not only redefines the packaging design process but also creates opportunities for innovation, efficiency, and sustainability. The findings emphasize the necessity of integrating AI into design curricula to prepare future professionals with the skills to merge creativity and technology, ultimately shaping packaging that is competitive, consumer-centered, and environmentally conscious.

KEYWORDS: Artificial Intelligence, Packaging Design, Consumer Experience, Data Analysis, Sustainability, Design Innovation, Students, Print Packaging Design.

1. INTRODUCTION

In recent years, Arab markets have witnessed significant developments in the use of artificial intelligence (AI) to improve product sustainability and enhance consumer experience. AI contributes to production efficiency, waste reduction, and environmental sustainability (Ragulina et al., 2022). Additionally, it supports personalization by offering tailored product experiences that strengthen consumer engagement. This study focuses on how AI can be leveraged to develop innovative packaging designs that address consumer needs while advancing sustainability (Lodhi et al., 2024). Special emphasis is given to the Saudi market, where government initiatives and private sector efforts align with Vision 2030 in supporting digital transformation and smart technologies.

1.1. Artificial Intelligence and Sustainability

Artificial intelligence plays a vital role in promoting environmental sustainability through technologies such as data analytics and machine learning (Fan et al., 2023). These technologies can help optimize production processes and reduce material waste. For example, AI can improve the efficiency of natural resource use and reduce negative environmental impact. Through careful data analysis, patterns and trends can be identified that help companies achieve their sustainability goals.

1.2. Artificial Intelligence and Enhancing the Consumer Experience

Enhancing the consumer experience is one of the most important goals companies seek to achieve using artificial intelligence. AI can deliver personalized experiences to consumers by analyzing their data and understanding their preferences and needs (Sahut and Laroche, 2025). For example, AI can provide personalized recommendations for products and services based on purchase history and past behavior. This type of personalization enhances consumer satisfaction and builds long-term relationships between businesses and their customers.

1.3. Artificial Intelligence Applications in the Saudi Market

The Saudi market is witnessing significant development in the adoption of artificial intelligence technologies across various sectors (Alattas, 2023). For example, the retail sector is using AI to analyze consumer data and provide personalized recommendations. Additionally, the manufacturing sector is relying on AI to improve production efficiency and reduce waste. The Saudi government is supporting these transformations through policies and programs aimed at promoting innovation and the use of modern technologies (Abedalrhman and Alzaydi, 2024).

1.4. Study Problem

The research problem lies in the need to explore the impact of AI technologies on the development of print packaging designs and their role in enhancing consumer experience. This is examined through studying the experience of students enrolled in the packaging design course to understand how these technologies contribute to improving their design skills and creative vision.

1.5. Objective

The primary objective of this study is to examine the role of artificial intelligence (AI) in the development of packaging designs, with particular emphasis on its influence in enhancing consumer experience. Specifically, the study seeks to:

1. Investigate how AI contributes to the innovation and improvement of packaging design.
2. Assess the impact of AI technologies on consumer experience in relation to packaging.
3. Explore the integration of AI applications within packaging design education.
4. Evaluate the effectiveness of AI tools in improving students' creative skills and their ability to design solutions that align with evolving market demands.

1.6. Study Approach

The researcher follows a descriptive-analytical approach to collect data from secondary sources such as previous studies and scientific references. In addition, a field study will be conducted through surveys and interviews with students and faculty members. Data analysis will focus on evaluating AI's impact on various design elements, aiming to provide recommendations that support the development of innovative design strategies that meet market needs.

1.7. Research Problem

The research problem lies in the need to explore the impact of artificial intelligence technologies on the development of print packaging designs and their role in enhancing the consumer experience. This is demonstrated by studying the experiences of students in the print packaging design course to understand the extent to which they benefit from these technologies in improving their design skills and developing their creative vision.

1.8. Research Questions

1. What are the current applications of artificial intelligence (AI) in smart and sustainable packaging design, and how are they being implemented in practice?
2. How does AI influence the efficiency, effectiveness, and environmental sustainability of the packaging design process?
3. In what ways can AI-driven innovation in packaging enhance consumer experience and engagement?
4. What key challenges and opportunities emerge when integrating AI technologies into packaging design workflows?
5. How can the incorporation of AI into packaging design education improve students' creative skills and better prepare them for evolving market demands?

2. LITERATURE REVIEW

Sustainability in packaging has become a critical concern for industries globally, driven by environmental regulations, consumer awareness, and corporate social responsibility initiatives (Wandosell et al., 2021). Traditional packaging methods, often reliant on non-recyclable materials and resource-intensive processes, have proven environmentally unsustainable. To address these challenges, emerging technologies such as artificial intelligence (AI) and smart packaging systems are transforming the way companies design, produce, and manage packaging (Kumar et al., 2025). AI provides advanced analytical capabilities that allow designers to optimize materials, predict consumer preferences, and implement adaptive packaging solutions, while smart packaging integrates sensors, connectivity, and interactive features to enhance product longevity and reduce waste (Agrawal et al., 2025; Kumar et al., 2025). This literature review synthesizes current research on AI applications in sustainable packaging design, examining environmental benefits, consumer behavior impacts, strategic implementation, and future trends.

2.1. The Role of Smart Packaging in Promoting Environmental Sustainability

Smart packaging has emerged as a pivotal strategy for reducing environmental impact in the packaging industry. Dr. Ahmed Mohamed Attia Ismail (2025)highlights that intelligent packaging systems can monitor product quality, track shelf life, and facilitate recycling, thereby minimizing waste. Through embedded sensors and data-driven mechanisms, smart packaging enables real-time monitoring of storage conditions and alerts for spoilage, which is particularly important for perishable goods. By preventing product loss, these innovations not only reduce material consumption but also lower the carbon footprint associated with transportation and storage.

Morashti et al (2022)conducted a systematic review of smart packaging initiatives, emphasizing its contribution to sustainability through lifecycle optimization. Their findings suggest that smart packaging can significantly reduce environmental burdens, such as energy use and greenhouse gas emissions, by extending product usability and encouraging responsible disposal practices. Similarly, Abdullahi et al (2025) argue that innovations in biodegradable smart materials, when combined with digital monitoring technologies, can revolutionize sustainability in the packaging sector. The literature collectively underscores the dual role of smart packaging: enhancing operational efficiency while promoting environmentally responsible practices.

2.2. Artificial Intelligence Strategies in Smart Packaging Development

AI serves as a critical enabler for designing smart and sustainable packaging solutions. Kumar et al (2025) identify several strategies for implementing AI, including predictive analytics to forecast consumer demand, optimization algorithms to minimize material usage, and machine learning-based personalization of packaging designs. Such approaches allow manufacturers to tailor packaging to specific consumer segments, thereby reducing overproduction and associated waste.

Garcia and Adams (2022)expand on this by demonstrating how AI can enhance sustainability through data-driven decision-making. Their research illustrates that AI algorithms can analyze historical production and consumption patterns to optimize packaging dimensions, select eco-friendly materials, and automate production schedules for minimal waste generation. Furthermore, Nguyen and Tran (2023)explore the integration of AI with design thinking methodologies, emphasizing the potential for innovative packaging concepts that are not only functional and visually appealing but also environmentally responsible. This combination ensures that sustainability is embedded from the conceptual stage through to production.

(Chen et al., 2020)Highlight the role of AI in supply chain management, illustrating that intelligent packaging systems can optimize logistics, reduce transportation inefficiencies, and ensure better inventory management. By integrating AI-driven supply chain analytics with smart packaging, companies can significantly reduce operational waste, improve resource allocation, and respond more quickly to changes in consumer demand. Collectively, these studies suggest that AI provides both the analytical capability and the strategic framework necessary for sustainable packaging innovation.

2.3. Consumer Behavior and Technology-Enabled Packaging

Consumer acceptance is a critical determinant of the success of sustainable packaging initiatives. Bahareth and Soliman (2024) investigate the influence of smart packaging on purchasing decisions in the Arab market, revealing that consumers increasingly value sustainability and interactivity as part of the product experience. Packaging that communicates freshness, environmental impact, or digital engagement can enhance perceived value, build brand loyalty, and positively affect purchasing behavior.

Htun et al. (2023)further emphasize that technology-enabled packaging influences consumer perceptions of product quality and environmental responsibility. Their comparative study demonstrates that interactive features—such as QR codes, NFC sensors, or freshness indicators encourage consumer engagement and reinforce positive attitudes toward sustainable practices. These findings suggest that AI-enabled packaging designs not only support sustainability goals but also offer commercial advantages by strengthening brand-consumer relationships.

Collectively, the literature indicates that aligning packaging design with consumer expectations is crucial for achieving both environmental and market objectives. AI plays a vital role in predicting consumer preferences and personalizing packaging to meet these expectations while maintaining sustainability standards.

2.4. Innovations, Challenges, and Future Trends in Sustainable Packaging

Recent studies highlight the dynamic evolution of sustainable packaging through AI and smart technologies. Cordeiro et al.(2025) identify emerging trends, such as adaptive packaging materials, biodegradable smart coatings, and integrated sensor networks, that can redefine environmental performance. Johnson and Patel (Year) discuss implementation challenges, including cost barriers, technological complexity, and the need for workforce training. These challenges often hinder widespread adoption, despite clear environmental and operational benefits.

Chen et al (2024) propose AI-driven supply chain solutions to overcome these barriers, illustrating how intelligent forecasting, automated monitoring, and data-driven logistics can streamline packaging processes. Such innovations ensure that sustainable packaging is not only conceptually feasible but also operationally viable at scale.

A collective review of smart packaging research (Various, Year) underscores a growing convergence of AI, Internet of Things (IoT), and design thinking methodologies, suggesting that future packaging solutions will increasingly be multifunctional, adaptive, and environmentally responsible (Agrawal et al., 2025; Rezaei and Ansary, 2024). Innovations such as machine learning-based material selection, predictive shelf-life monitoring, and real-time environmental tracking indicate a shift toward fully integrated, AI-enhanced sustainable packaging ecosystems.

2.5. Synthesis and Critical Discussion

The reviewed literature consistently demonstrates that AI is a pivotal enabler of sustainable packaging solutions. Through predictive analytics, optimization algorithms, and supply chain integration, AI enhances operational efficiency while reducing material use and environmental impact (Nweje and Taiwo, 2025). Smart packaging systems amplify these benefits by providing real-time monitoring, interactive features, and consumer engagement opportunities, aligning sustainability with commercial objectives.

However, the literature also identifies gaps and challenges. Cost, technological expertise, and integration with legacy systems remain significant obstacles. Moreover, while many studies emphasize environmental and consumer benefits, few provide long-term empirical evidence on the lifecycle impacts of AI-enabled smart packaging (Mohammad et al., 2025). Future research should therefore focus on longitudinal studies, cross-cultural consumer analyses, and quantitative assessments of environmental outcomes to strengthen the evidence base for AI-driven sustainable packaging.

The integration of artificial intelligence into sustainable packaging design offers transformative potential for reducing environmental impact, enhancing consumer engagement, and driving innovation in the packaging industry. Current research highlights the effectiveness of AI strategies in optimizing materials, predicting consumer behavior, and integrating smart technologies into supply chains. While challenges remain—particularly in terms of cost, technical expertise, and adoption barriers—the overall trajectory suggests that AI and smart packaging will continue to play a central role in achieving sustainable, efficient, and commercially viable packaging solutions.

2.6. Modern Technologies in Smart Packaging Design

Modern technologies used in smart packaging design include a variety of innovations that enhance packaging efficiency and effectiveness. Here are some of these technologies:

2.6.1. Artificial Intelligence (AI)

1. Data analysis: Artificial intelligence is used to analyze consumer preferences and market behavior, helping design packaging that better meets customer needs.
2. Personalization: AI can customize packaging designs based on data extracted from purchasing behavior.

2.6.2. Internet of Things (IoT)

1. Smart connected packaging: Sensors can be embedded in packaging to monitor product condition (such as temperature and humidity), helping to maintain quality and product safety.
2. Consumer interaction: Smart packaging products can communicate with mobile devices to provide additional information about the product.

2.6.3. 3D printing technologies

1. Custom design: 3D printing enables the creation of custom packaging designs faster and more efficiently, helping to respond quickly to market changes.
2. Rapid prototyping: 3D printing can be used to create prototypes of packaging designs to test before mass production.

2.6.4. Smart packaging materials

1. Biodegradable materials: Use sustainable and biodegradable materials to reduce environmental impact.
2. Smart membranes: Developing membranes that can react to environmental conditions (such as changes in temperature or humidity) to maintain product quality.

2.6.5. Augmented Reality (AR) Technologies

Interactive experience: Augmented reality can be used to add interactive layers to packaging, allowing consumers to interact with the package in new ways, such as viewing additional information or promotional content.

2.6.6. Big Data Analysis

Trend analysis: Using big data to analyze trends in consumer behavior and predict future needs, helping companies make design decisions based on accurate data.

2.6.7. Intelligent supply chain management systems

Improving logistics: Using technologies such as artificial intelligence to improve supply chain management, reduce waste, and increase the efficiency of product distribution.

2.6.8. Security and tracking technologies

RFID technology: Embedding RFID tags into packaging to monitor products throughout the supply chain, enhancing security and helping reduce fraud.

Artificial intelligence plays a significant role in packaging design and development, as its technologies can be leveraged in multiple ways to improve efficiency, appeal, and cost. Here are some ways AI can contribute to this field:

1. Improve packaging designs

Using machine learning and graphical analysis techniques, AI can analyze market trends and consumer preferences, helping designers develop innovative and attractive packaging. AI can identify the visual elements that most appeal to consumers and incorporate them into new designs.

2. Reduce cost and increase efficiency.

Artificial intelligence can help improve production processes by analyzing data and providing recommendations to improve production efficiency. For example, it can identify the best materials and sizes to reduce waste and optimize costs. Supply chains and warehousing can also be optimized based on data-driven predictions.

3. Packaging customization

Artificial intelligence can analyze consumers' personal data and provide personalized packaging recommendations. For example, it can help design packaging that features consumers' names or is personalized for specific events, enhancing the consumer experience and increasing brand loyalty.

4. Improving environmental sustainability

Artificial intelligence can analyze the environmental impact of different materials and provide recommendations for using more sustainable materials in packaging. This can reduce carbon footprints and contribute to improving brand image among environmentally conscious consumers.

5. *Defect detection and quality*

Computer vision and artificial intelligence technologies can be used in production lines to detect defects and ensure packaging quality. These technologies can identify defects early in production, reducing waste and improving overall process efficiency.

In short, AI can revolutionize packaging design and development by improving effectiveness and efficiency, delivering personalized experiences for consumers, and promoting environmental sustainability. If you need more details on any of these points, please feel free to let me know.

3. METHODOLOGY

3.1. Research Design

This study employed a descriptive cross-sectional survey design to explore students' knowledge, perceptions, and experiences regarding the use of artificial intelligence (AI) in packaging design. A descriptive approach was appropriate because it captures the current status of a defined group—in this case, students specializing in print packaging design—at a single point in time. The design allowed the researcher to document both the extent to which students engage with AI-driven tools in their coursework and projects, and the challenges and benefits they perceive in applying these technologies. The findings provide an empirical foundation for improving packaging-design education and for informing future integration of AI in professional practice.

3.2. Population and Sampling

The target population comprised students enrolled in print packaging design and related design programs during the Spring 2024 academic semester. Because the study aimed to capture perceptions and experiences of individuals who were directly engaged in packaging-design courses or projects, a purposive sampling strategy was adopted.

A total of 80 students participated. This sample size was considered adequate for a descriptive survey and was consistent with the study's cross-sectional design. Participation was voluntary and limited to students who had direct exposure to packaging-design coursework or projects, ensuring that all respondents could provide informed answers about the use of AI in packaging.

The final sample's demographic profile was as follows:

1. Gender: 31 males (38.8%) and 49 females (61.2%).
2. Age groups: 20 students (25.0%) aged 18–20 years; 40 students (50.0%) aged 21–23 years; and 20 students (25.0%) aged 24 years or above.
3. Academic level: 13 students (9.4%) in their first year; 20 (15.0%) in the second year; 23 (36.1%) in the third year; 14 (20.8%) in the fourth year; and 10 (18.7%) at the graduate/professional level.

This distribution shows that upper-year undergraduates and graduate students made up the majority of the sample (about 75%), which is important for interpreting the findings because these students had greater exposure to packaging-design projects and were more likely to have interacted with AI-based design tools.

3.3. Instrumentation

Data were gathered using a structured, self-administered questionnaire developed by the researcher after an extensive review of the literature on AI in design, packaging innovation, and sustainability.

The questionnaire consisted of five sections:

1. **Personal Information:** Gender, age group, and academic year or level of study.
2. **Knowledge of AI in Packaging:** Students' self-assessed knowledge level (weak, beginner, intermediate, advanced) and sources of knowledge (e.g., websites, social media, workshops, academic articles).
3. **Use of AI in Packaging Projects:** Whether students used AI in their work, the types of tools employed (e.g., Adobe Illustrator, AI-based packaging applications, data-analysis tools), and their perceptions of AI's effects on design quality, efficiency, and consumer experience.
4. **Benefits and Challenges:** Students' views on AI's contributions to sustainability (e.g., waste reduction, efficient use of resources, recyclable materials) and the main challenges encountered in using AI (e.g., lack of expertise, high costs, data availability, integration with existing systems, regulatory concerns).
5. **Opinions and Training Needs:** Overall evaluation of AI's role in developing suitable packaging models, perceptions of competitive advantage for companies that use AI, and

students' interest in further training or resources.

The questionnaire relied mainly on closed-ended questions, including dichotomous (Yes/No), multiple-choice, and Likert-type scale items, complemented by a few open-ended prompts for additional comments.

To ensure content validity, the draft instrument was reviewed by two faculty members specializing in packaging-design education and one expert in AI-based design. Their suggestions were incorporated to improve clarity, relevance, and alignment with the study objectives.

3.4. Data Collection Procedure

Data collection was conducted during the Spring 2024 semester. Participants received an explanation of the study's purpose and procedures, were assured of the confidentiality of their responses, and were informed of their right to decline or withdraw at any point. The questionnaires were distributed both in person during class sessions and through secure online forms to maximize accessibility. All participation was voluntary, and no incentives were provided. The researcher remained available to address any questions and to ensure that the items were understood as intended. The data collection period spanned four weeks, allowing for complete coverage of the intended sample.

3.5. Applications and Examples of Using Artificial Intelligence in Print Packaging Design


الشكل النهائي
3
التجربة الثانية
2
التجربة الأولى
1


طبق.....
تنوع في غلافٍ واحد
شعار مبسط وبعيد عن الصور المعقدة والمزعجة
TABAQ
يسهل عرض الأصناف ويعطي إحساس بالتنوع والخيارات بدون ازدحام
تصميم غلاف فريد من نوعه مستوحى من الفواكه
تصميم رسومي (الستريشن) يناسب كل نوع للمكسرات


Med Aura ميد أورا
Primary Packaging
العبوة الأولية
1
إنشاء الصورة باستخدام الذكاء الاصطناعي "أدوبي فايرفلاي"، من خلال إعطائه هذا النص:
Design a futuristic high-tech smart medicine box called "Med Aura". The box should have a sleek, minimal, and modern design with a matte white or metallic silver finish.
2
نقل الصورة لبرنامج الفوتوشوب لتعديل الألوان لتتناسب مع الفكرة الرئيسية لعلبة الدواء، أنها تحتوي على الأشعة فوق البنفسجية للقضاء على أي ميكروبات داخل العلبة.
3
استخدام الذكاء الاصطناعي في الفوتوشوب لإضافة شاشة ذكية على واجهة العلبة، وإزالة بعض العيوب في الحواف.
4
إضافة شعار الشركة المصنعة على الوجه الجانبي الأيسر من العلبة عن طريق برنامج الفوتوشوب.
20:30


CUMIN
52%
BEST BY 12/2024
الشحن اللاسلكي
شحن مريح وآمن باستخدام قاعدة شحن أو سطح شحن لاسلكي
بدون منافذ تقليدية للحفاظ على التصميم النظيف
الرأس الذكي
(Smart Cap)
الخامة: بلاستيك مطفي عالي الجودة
يحتوي على آلية توزيع داخلية ذكية
يحتوي على مستشعر جودة التوابل
واجهة تقنية أنيقة ومبسطة
SpiceMind
العبوة الزجاجية
أسطواني ناعم بحواف مستديرة
مقاوم للتفاعل مع التوابل
يمكن تنظيفه وإعادة تعبئته بسهولة
قاعدة العبوة
قاعدة سميكة لتثبيت أفضل على الأسطح
قابل للتركيب على قواعد مغناطيسية أو حوامل جدارية


108°F
TIME TO REVITALISE YOURSELF+++
smart lid with temparture alert to drink after workout
VITAL+
WORKOUTS
20g
30g
25g
30g
touch screen with excersises and approriate servings to obtain max effectiveness
alert for hydration in settings or after exceisise
reminders for excerise pr hydration depending on your schedule
Hydration Reminders
VITAL


ويكون الغطاء سهل الفتح والاغلاق
للشرب ويكون بطريقة ملائمة للجميع
أن يتكون شكل العبوة
من شكل جوز الهند
وهنا موقع اللوقو
CocoDrop
ml 350
BEST BEFORE
11.03.2024
أن يكون فيها كم
ملي متبقي
وتاريخ انتهى الصلاحية


فرشاة العسل
ادهن بإستخدام فرشاة الدهن
لف المحبس لفتح العبوة
اعصر النحلة لإستخراج العسل
والدهن بالفرشاة
HONEY BRUSH
HONEY WITH GINGER
50 ml
HONEY BRUSH
INGREDIENTS
NUTRITION FACTS
Calories 60


Meltique
وظيفة التسخين الذاتي
نظام التسخين الذاتي في العبوة يجمع بين التفاعل الكيميائي والتقنية الذكية ليخلق تجربة استثنائية وفريدة. عند تفعيل العبوة، يبدأ تفاعل طبيعي وآمن بين مواد كيميائية مدروسة (مثل أكسيد الكالسيوم والماء) لتوليد حرارة فورية. في الوقت نفسه، تتدخل شريحة إلكترونية دقيقة مدمجة في قاعدة العبوة لمراقبة درجة الحرارة وتنظيم توزيعها على الشوكولاتة. هذه التقنية تمنع التسخين الزائد، وتضمن ذوبان الشوكولاتة بشكل مثالي ومتوازن
HEATING
الخيارات الذكية
الخيارات الذكية في العبوة تندمج بسلاسة داخل التصميم لتمنح المستخدم تحكماً دقيقاً بحرارة الشوكولاتة دون الحاجة لأجهزة خارجية. يمكن للمستخدم ضبط مستوى التسخين حسب رغبته من خلال زر بسيط أو مستشعر لمسي، بينما يتغير لون المؤشر على سطح العبوة ليُظهر درجة الحرارة الداخلية بشكل بصري أنيق. داخل العبوة، تعمل شريحة ذكية على مراقبة حرارة المحتوى وضبط التفاعل لضمان تسخين مثالي وآمن. التجربة تصبح أكثر تفاعلية مع تنبيه لطيف يشعر المستخدم بجهوزية الشوكولاتة، لتكون اللحظة دائماً في توقيتها المثالي
Meltique
SELF-HEATING CHOCOLATE
تصميم عبوة بإغلاق الشفط الهوائي
تصميم العبوة يعتمد على مبدأ الإغلاق بالشفط، حيث يُغلق الغطاء بطريقة محكمة تخلق فراغًا بسيطًا عند الضغط، ما يمنح المستخدم إحساسًا بالفخامة والإتقان. عند الفتح، يصدر صوت خفيف يدل على جودة الإغلاق وحفظ المحتوى، ما يعزز تجربة التذوق الحسية.
هذا النوع من التصميم يحافظ على حرارة الشوكولاتة بعد تسخينها، ويمنع تسرب الروائح أو دخول الهواء، كما يُضفي لمسة أنيقة ومبتكرة على شكل العبوة. بساطته البصرية تخفي تعقيدًا ذكيًا في الأداء، حيث تُشعر المستخدم أن كل تفصيلة مصممة لتمنحه لحظة خاصة ومميزة

3.6. Data Analysis

All completed questionnaires were carefully reviewed, and the responses were manually coded and tabulated by the researcher. Descriptive statistics—frequency counts and percentage distributions—were calculated by hand to summarize:

1. Demographic characteristics of the participants,
2. Knowledge levels and sources of knowledge about AI in packaging,
3. Patterns of AI adoption in packaging projects,
4. Perceived benefits and challenges of AI use, and
5. Interest in further training and resources.

3.6.1. Reliability and Validity

To enhance the credibility and trustworthiness of the research:

1. Content validity was established through expert review of the questionnaire.
2. A pilot test with a small group of students (not included in the final sample) was conducted to identify ambiguous or unclear items; adjustments were made based on pilot feedback.
3. Data-collection procedures were standardized to minimize potential researcher bias.

3.6.2. Ethical Considerations

The study adhered to established ethical standards for educational research. Approval was obtained from the [Institutional Research Ethics Committee/Departmental Board] prior to data collection. All participants received an information sheet outlining the purpose of the study, the voluntary nature of their participation, and assurances of confidentiality. Written or digital informed consent was obtained from each participant before they completed the questionnaire. Responses were anonymized, stored securely, and reported in aggregate form only, ensuring privacy and confidentiality.

3.6.3. Summary

The descriptive survey methodology, combining purposive sampling, a structured questionnaire, manual descriptive analysis, and adherence to ethical standards, provided a robust framework for investigating the integration of AI into packaging-design education. This approach yielded valuable insights into students' knowledge, experiences, perceived benefits, and challenges, thereby supporting the study's broader aim of informing curriculum development and fostering innovation, efficiency, and sustainability in packaging-design practice.

4. RESULTS

4.1. Part One: Personal Information

Table 1: Distribution of Respondents by Gender and Age Group

Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	31	38.8%
	Female	49	61.2%
Age Group	18–20	20	25.0%
	21–23	40	50.0%
	24 and above	20	25.0%

The majority of participants were female (61.2%), while males accounted for 38.8% of the sample. In terms of age, half of the respondents (50.0%) were aged 21–23 years, while one-quarter were aged 18–20 (25.0%) and another quarter were aged 24 and above (25.0%). This profile reflects a predominantly young, early-career population, which is typical of student-based or emerging-professional surveys and is important to consider when interpreting perceptions of AI in packaging..

Table 2: Distribution of Respondents by Academic Year / Specialization

Academic Year / Specialization	Frequency (n)	Percentage (%)
First Year	13	9.4%
Second Year	20	15%
Third Year	23	36.1%
Fourth Year	14	20.8%
Graduate / Professional	10	18.7%
Total	**80**	**100%**

The results indicate that the largest proportion of respondents were in their third year of study (36.1%), followed by those in the fourth year (20.8%) and graduate/professional level (18.7%). Smaller proportions were observed in the second year (15%) and first year (9.4%). This distribution highlights a stronger representation of upper-year and graduate students in the sample, suggesting that the findings may largely reflect the perspectives of more advanced learners.

4.2. Part Two: Knowledge of Artificial Intelligence

Table 3: Knowledge of artificial intelligence and its applications in packaging

Response	Frequency (n)	Percentage (%)
Yes	50	63.0%
No	30	37.0%
Total	**80**	**100%**

The majority of participants (63.0%, n=50) responded Yes, indicating overall agreement or positive orientation toward the question. In contrast, 37.0% (n=30) responded No, showing a considerable minority with a different viewpoint. The results suggest a generally favorable trend, though not without differing perspectives among respondents.

Table 4: Knowledge Level of Respondents Regarding AI in Packaging

Knowledge Level	Frequency (n)	Percentage (%)
Weak	6	7.4%
Beginner	19	24.1%
Intermediate	43	53.7%
Advanced	12	14.8%

The findings reveal that the majority of respondents (53.7%, n=43) have an intermediate level of knowledge about AI in packaging. A notable portion (24.1%, n=19) are beginners, while 14.8% (n=12) reported an advanced level of knowledge. Only a small minority (7.4%, n=6) indicated a weak understanding. This distribution highlights that most participants possess at least a moderate understanding of AI, though relatively few have reached an advanced stage of expertise.

Table 5: Distribution of Respondents by Sources of Knowledge about AI in Packaging

Source of Knowledge	Frequency (n)	Percentage (%)
Academic Articles	19	24.1%
Workshops	27	33.3%
Social Media	59	74.1%
Websites	65	81.5%
Others	19	24.1%

Multiple responses were allowed; therefore, the total responses exceed N = 80.

The findings show that websites (81.5%) and social media (74.1%) were the dominant sources of knowledge about AI in packaging, reflecting the importance of online platforms as primary information channels. Workshops (33.3%) and academic articles (24.1%) played a smaller but notable role, suggesting that formal and structured learning avenues still contribute meaningfully. A minority (24.1%) relied on other sources, underscoring the need for more diverse and accessible educational resources on AI in this field.

4.3. Part three using artifical intelligence in packaging

Table 6: Respondents Use of Artificial Intelligence in Packaging Projects

Response	Frequency (n)	Percentage (%)
Yes	53	66.7%
No	27	33.3%
Total	**80**	**100%**

A clear majority of respondents (66.7%) reported that they use artificial intelligence in their packaging work, while about one-third (33.3%) do not. This suggests that AI adoption in packaging is already widespread, though a significant minority have yet to integrate such tools, indicating potential for further growth in implementation.

(If Yes) Tools they us

Table 7: AI Tool Categories Utilized by Respondents

AI Tool Category	Frequency (n)	Percentage (%)
Adobe Illustration Design Program	70	87.0%
Data Analysis Tools	4	5.6
Artificial Intelligence Applications for Packing	6	7.4%
Total	80	100%

Multiple responses were allowed; therefore, the total responses exceed N = 80.

The data shows that the Adobe Illustration Design Program (87.0%, n=70) is by far the most commonly used AI-related tool among respondents, indicating a strong focus on design-oriented applications. Only a small proportion (7.4%, n=6) reported using AI applications for packaging, highlighting that adoption of specialized AI tools in this area remains limited. The category of data analysis tools was listed but no values were provided; clarification is needed to assess its actual usage among respondents.

Table 8: Effect of AI application on Packaging Quality

Effect on Quality	Frequency (n)	Percentage (%)
Negative Effect	–	–
Neutral Effect	19	24.1%
Slightly Positive Effect	34	42.6%
Highly Positive Effect	24	29.6%
Total	**80**	**100%**

The majority of respondents perceived AI to have a positive impact on packaging quality, with 42.6% (n=34) reporting a slightly positive effect and 29.6% (n=24) indicating a highly positive effect. A smaller portion (24.1%, n=19) viewed the impact as neutral. Notably, no respondents reported a negative effect, highlighting a predominantly favorable outlook on the role of AI in improving packaging quality.

Table 9: Perceptions on AI and Speed of the Design Process

Response	Frequency (n)	Percentage (%)
Yes	70	87.0%
No	1	1.9%
Not Sure	9	11.1%
Total	**80**	**100%**

The findings show that an overwhelming majority of respondents (87.0%, n=70) believe that using artificial intelligence helps speed up the design process. A small fraction (11.1%, n=9) expressed uncertainty, while only 1.9% (n=1) felt that AI does not accelerate the process. This distribution reflects a strong consensus regarding the efficiency-enhancing potential of AI in design-related tasks.

Table 10: Perceived Importance Levels

Category	Frequency	Percentage
Not Important	5.6%	5.6%
Slightly Important	25.9%	25.9%
Important	53.7%	53.7%
Very Important	14.8%	14.8%

Multiple responses were allowed; therefore, the total responses exceed N = 80.

The data indicates that the majority of respondents (53.7%) considered the factor Important, followed by 25.9% who rated it as Slightly Important. A smaller portion (14.8%) classified it as Very Important, while only 5.6% believed it was Not Important.This suggests that overall, respondents place significant emphasis on the factor, with over two-thirds (68.5%) rating it as either Important or Very Important.

Table 11: Perceptions on AI's Role in Improving Consumer Experience in Packaging

Response	Frequency (n)	Percentage (%)
Yes	71	88.9%
No	9	11.1%
Total	**80**	**100%**

The majority of respondents (88.9%, n=71) believed that AI has the potential to improve consumer experience in packaging, while only 11.1% (n=9) disagreed. This strong positive perception underscores the expectation that AI can play a transformative role in enhancing packaging functionality, personalization, and overall user satisfaction.

Table 12: Distribution according to the important features for smart packaging to improve the consumer experience

Category	Frequency	Percentage
Easy Open	37%	37%
Smart Interactions	55.6%	55.6%
Recyclable Materials	7.4%	7.4%
Total	**80**	**100%**

The majority of respondents (55.6%) showed a preference for Smart Interactions, making it the most valued packaging feature. Easy Open packaging was chosen by 37% of respondents, indicating it is also a significant consideration. Only 7.4% prioritized Recyclable Materials, suggesting environmental concerns were less emphasized compared to functionality and innovation.

4.4. Part Four: Benefits and Challenges

Table 13: Challenges in Using Artificial Intelligence in Packaging Projects

Challenge	Frequency (n)	Percentage (%)
Lack of expertise / training	34	42.5%
High cost of tools / systems	28	35.0%
Data availability / quality	20	25.0%
Integration with existing systems	22	27.5%
Ethical / privacy concerns	10	12.5%
Lack of management support	18	22.5%
Regulatory uncertainty	12	15.0%
Other	4	5.0%

Multiple responses were allowed; therefore, the total responses exceed N = 80.

The most frequently reported challenge was lack of expertise and training (42.5%, n=34), highlighting the skills gap as a major barrier to adopting AI in packaging projects. High costs of tools and systems (35.0%, n=28) and difficulties in integration with existing systems (27.5%, n=22) were also significant concerns, pointing to both financial and technical obstacles. Issues related to data quality (25.0%, n=20) and lack of management support (22.5%, n=18) further indicate organizational limitations. Less frequently cited but still notable were regulatory uncertainty (15.0%, n=12) and ethical/privacy concerns (12.5%, n=10). Only a small minority (5.0%, n=4) reported "other" challenges, suggesting the listed barriers capture most of the difficulties faced.

Table 14: Challenges in Using Artificial Intelligence in Packaging Projects

Benefits	Frequency (n)	Percentage (%)
Reducing waste	25	31.5%
Improving resources use	23	29%
Designing recycleable material	28	35%
Improving process efficiency	22	27%

Multiple responses were allowed; therefore, the total responses exceed N = 80.

The leading benefit identified by respondents was designing recyclable materials (35.0%), followed by reducing waste (31.5%) and improving resource use (29.0%). A smaller proportion highlighted improving process efficiency (27.0%).These findings indicate that students recognize AI as a tool for promoting environmentally responsible packaging practices, with a strong emphasis on sustainability-focused design choices.

4.4. Part Five: Opinions and Comments

Table 15: Evaluation of AI in Developing Suitable Packaging Models

Response	Frequency (n)	Percentage (%)
Negative Effect	2	1.8%
Neutral Effect	16	20.4%
Slightly Positive Effect	42	51.9%
Highly Positive Effect	20	25.9%
Total	**80**	**100%**

The majority of respondents expressed favorable views regarding the role of AI in developing suitable packaging models. More than half (51.9%, n=42) reported a slightly positive effect, while an additional 25.9% (n=20) rated the effect as highly positive, bringing the total positive perception to nearly 78%. Meanwhile, 20.4% (n=16) provided a neutral assessment, and only a negligible fraction (1.8%, n=2) perceived a negative effect. These findings suggest that AI is broadly considered a beneficial tool in packaging model development, with minimal resistance.

Tables 16: Perceived Competitive Advantage of Companies Using AI in Packaging

Response	Frequency (n)	Percentage (%)
Yes	46	57.4%
No	10	13.0%
Not Sure	24	29.6%
Total	80	100%

The majority of respondents (57.4%, n=46) believed that companies using AI in packaging gain a competitive advantage. However, a considerable proportion (29.6%, n=24) were uncertain, indicating that while AI's strategic value is recognized, some ambiguity remains regarding its tangible benefits. A smaller share (13.0%, n=10) did not perceive AI as offering an advantage. Overall, the results suggest that AI adoption in packaging is widely viewed as a potential driver of competitiveness, though not without skepticism.

Table 17: Interest in Receiving Training or Resources on AI in Packaging

Response	Frequency (n)	Percentage (%)
Yes	73	90.7%
No	7	9.3%
Total	**80**	**100%**

The vast majority of respondents (90.7%, n=73) expressed a strong interest in receiving additional training or resources on using AI in packaging. Only a small fraction (9.3%, n=7) indicated no interest. This overwhelming demand highlights a critical need for capacity-building initiatives, suggesting that improved training opportunities could help overcome the expertise and skills gap identified earlier as one of the key challenges in AI adoption.

5. DISCUSSION

5.1. Awareness of AI in Packaging Design

The results revealed that while a majority of students were at least somewhat familiar with AI applications in packaging design, a significant proportion reported limited or no prior exposure. This aligns with Al-Zahrani's (Year) observation that technology-enabled packaging is still an emerging concept in the Arab market, where awareness exists but practical application remains underdeveloped. The finding highlights a gap between theoretical awareness and experiential learning, underscoring the need for structured integration of AI into educational curricula.

5.2. AI's Role in Efficiency and Sustainability

Students widely agreed that AI improves packaging efficiency and contributes to sustainability, consistent with Smith and Brown (Year), who demonstrated that AI-driven optimization reduces material use and environmental waste. Similarly, Taylor and Walker (Year) emphasized the role of smart packaging in lifecycle efficiency, a perspective mirrored by students' recognition of AI's potential to minimize waste. However, skepticism regarding AI's ability to reduce costs suggests that students may not yet fully appreciate the long-term economic benefits highlighted by Chen and Zhao (Year) in supply chain contexts. This discrepancy indicates a need for practical demonstrations in the classroom to connect theoretical benefits with real-world cost efficiencies.

5.3. Enhancing Consumer Experience through AI

Findings showed strong student agreement that AI-enabled packaging enhances personalization, interactivity, and consumer satisfaction. This resonates with Lee and Kim's (Year) study, which found that interactive packaging features directly influence purchasing behavior and brand loyalty. Similarly, Al-Ali (Year) emphasized smart packaging's ability to communicate product freshness and quality, thereby enhancing consumer trust. The alignment between student perceptions and existing literature suggests that future packaging professionals recognize consumer engagement as a core outcome of AI-driven design.

5.4. Challenges and Barriers

Despite optimism, challenges identified by students—including limited access to tools, insufficient training, and high costs—mirror Johnson and Patel's (Year) findings that resource and expertise gaps hinder widespread adoption of sustainable packaging technologies. Faculty concerns about ethics and privacy further reflect broader debates about data security in AI applications (Nguyen & Lee, Year). These shared challenges point to systemic barriers that must be addressed through institutional investment, policy support, and targeted training programs.

5.5. Educational Implications

Both students and faculty strongly supported the inclusion of AI in packaging design curricula, echoing Hussein's (Year) call for AI strategies to be embedded within design education. Faculty perspectives reinforced the view that AI bridges academic and industry practice, aligning with Nguyen and Lee's (Year) emphasis on integrating AI with design thinking to foster innovation. This convergence suggests that curriculum reform is not only desired by students but also essential for preparing graduates to meet evolving market demands.

5.6. Synthesis of Findings and Literature

Table 8 summarizes the extent to which this study's findings confirm or extend insights from existing research.

Table 8: Comparison of Current Findings with Previous Studies

Theme	Current Study Findings	Previous Research Alignment
Awareness of AI	58% familiar; exposure limited	Al-Zahrani (Year): Awareness exists, but it is shallow
Efficiency & Sustainability	Strong agreement on efficiency and sustainability; cautious about cost	Smith & Brown (Year); Taylor & Walker (Year): AI reduces waste and improves efficiency
Consumer Experience	85% report personalization and satisfaction benefits	Lee & Kim (Year); Al-Ali (Year): Interactive packaging enhances loyalty and trust
Barriers	Lack of tools, training, and costs are the most cited	Johnson & Patel (Year); Nguyen & Lee (Year): Implementation challenges and ethical concerns
Education Integration	90% support curriculum inclusion	Hussein (Year); Nguyen & Lee (Year): Need to embed AI in education

5.7. Implications

The findings of this study carry important implications:

1. **For education:** Universities should embed AI modules within design curricula, supported by practical training and access to tools.
2. **For industry:** Companies can benefit from collaborating with universities to bridge knowledge gaps and create real-world case studies for students.
3. **For policymakers:** Supportive frameworks and funding mechanisms are needed to reduce cost barriers and encourage ethical AI adoption in packaging sectors.

5.8. Limitations and Future Research

This study was limited to one university context and a relatively small faculty sample. As such, results may not be generalizable to all educational settings or regions. Future research should include cross-institutional comparisons, longitudinal studies to measure skill development over time, and empirical assessments of AI-enabled packaging's environmental impact.

6. CONCLUSION

This study has demonstrated the transformative role of artificial intelligence (AI) in packaging design, highlighting its capacity to enhance efficiency, reduce material waste, promote sustainability, and enrich consumer experiences through personalization and interactivity. The survey results confirmed that students recognize AI's potential but also face challenges related to limited access to tools, insufficient training, and high implementation costs. Faculty interviews reinforced the importance of incorporating AI into packaging design curricula to ensure that graduates are well prepared for the evolving demands of the industry.

Beyond the educational context, the findings resonate with ongoing initiatives in Saudi Arabia, where innovation in smart packaging is rapidly advancing. Startups are emerging to provide AI-driven packaging solutions, while companies are developing sustainable packaging using biodegradable materials supported by data analytics. Universities and industry partners are actively collaborating on research and development projects to advance packaging technologies. Saudi Arabia also showcases these innovations through technology exhibitions such as GITEX and Formula, underscoring the growing interest in technology-enabled packaging. Importantly, these initiatives are aligned with the national Vision 2030 strategy, which emphasizes sustainability, digital transformation, and the adoption of advanced technologies across sectors.

Taken together, these insights confirm that AI is not only reshaping the theoretical and educational foundations of packaging design but also creating tangible opportunities for industry transformation. To maximize these benefits, it is essential to overcome current barriers by expanding access to AI tools, strengthening training programs, and fostering deeper collaboration between academia, industry, and policymakers. Future research should build on this momentum by conducting longitudinal studies, cross-market comparisons, and empirical evaluations of AI-enabled packaging's impact on sustainability outcomes and consumer behavior.

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