INTERDISCIPLINARY COLLABORATION IN THE DESIGN PROCESS OF INTERACTIVE EXHIBITS FOCUSING ON NEW MATERIALS

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Abstract. The study reported in this paper focuses on the creation of captivating and innovative interactive science and technology museum exhibits by leveraging digital technology to support interdisciplinary collaborative design in the context of a rapidly evolving technological landscape. In introducing new prospects for science and technology museum exhibit design we focus on a specific theme-related question: How can the distinctive properties of graphene, a key future material, be made accessible in a high quality educational spatial experience through a collective, collaborative, and interdisciplinary design process that transcends boundaries of scale and conventional professional purview? To address this question, we first observed a multidisciplinary team comprising architects, material scientists, educational experts, and technology designers engaged in applied spatial interactive exhibit design for science and technology museums. Based on a critical analysis of this design process, we propose a new type of design workflow, leveraging the synergetic effects of interdisciplinary cooperation to foster novel types of digital spatial design approaches. The paper finally reports on the simulation and testing of the technical features of the designed exhibit and summarizes generalizable observations regarding the viability of the design process in broader contexts.

Keywords. Interdisciplinary Collaboration, Graphene Materials, Interactive Technology Exhibits, Technology Education, Digital Design Process.

1. Introduction

Interdisciplinary collaboration is becoming a key approach to promote educational development, technological innovation, and address complex problems. Interdisciplinary collaboration has been recognized as having a profound impact on creativity (Moirano et al., 2020) and is steadily encompassing an increasing number of fields. Digital technology has accelerated the process of interdisciplinary collaboration in the field of design. The collaborative design of an interactive exhibit

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for the Shenzhen science and technology museum that focuses on the display of the charging and discharging process of graphene materials offered rich opportunities to explore digitally mediated interdisciplinary design strategies. In the following sections, we present this science and technology museum exhibit design process case study, which aimed to provide visitors with immersive experiences, create engaging exhibitions, and effectively convey the unique characteristics of the advanced material graphene. Following this analysis, we finally discuss the opportunities and challenges arising from this design approach.

2. Background

Interdisciplinary collaboration, a team-based approach that involves multiple disciplines or professions, aims to address complex problems or study interdisciplinary topics based on shared goals and interests, effective communication and collaboration, investment of resources and time, as well as leadership and organizational skills. As Liu et al. (2021) show, interdisciplinary collaboration introduces novel ideas and methods for solving complex problems and drives scientific research forward. Dillon et al. (2021) applied Bronstein's interdisciplinary collaboration model to enhance special education services to improve service delivery and learner outcomes. Design is a highly complex field, and exhibit design, as a branch of it, covers many professional disciplines. This diversity provides a rich soil for innovative interdisciplinary collaboration, allowing designers to draw on knowledge and skills from various fields to create more creative and practical exhibits (Meyer et al. 2020, Wang et al. 2019). Therefore, when designing interactive exhibitions, we place a particular emphasis on the value and significance of cross-disciplinary collaboration.

In our case, the cooperation between professionals from different backgrounds (including architects, material scientists, educators, and technical designers) was a key determinant of depth and quality of exploration in the design and implementation of interactive exhibitions (Pei et al, 2023). In terms of exhibition content, we focused on educational approaches to cutting-edge advanced materials in the fields of science and technology, in particular graphene. Graphene is a two-dimensional material composed of carbon atoms, upon which materials scientists have been conducted in-depth research on for some time. The unique physical, chemical, and electronic properties of graphene are predicted to have a significant impact on design across all scales (Li et al. 2020). Despite the relevance of the material across many current technologies, the nanoscale material properties of graphene are not easy to grasp for a nonexpert audience, as confirmed by previous exhibitions (Fox, 2017). We propose that this knowledge gap can be addressed through the explorative and experiential approach to science and technology education fostered by contemporary museum exhibits. Beyond providing educational interactive experiences of advanced materials such as graphene to the public, such museum exhibits aim to inspire new generations to innovate ideas and applications in the fields of current and future science and technology.

3. Methodology

This paper adopts a case study approach and literature review to gain a deeper understanding of the design and implementation processes of interactive museum exhibitions. We previously observed a multidisciplinary team's practical application of interdisciplinary collaboration techniques and the use of advanced digital design tools (Midjourney V5 and chatGPT 3.5) as a bridge between diverse fields to achieve more effective collaboration.

Drawing on references of 40 scientific and technological exhibits and on-site observations of 30 science exhibits from several museums in Shenzhen, multiple dimensions of characteristics have been obtained, including data on most successful display themes and content, display methods, interaction forms, size and physical layout, user appeal, as well as the most successful characteristics determined based on principal component analysis (PCA). We then used digital design tools in the design process to create visual displays, scene descriptions, spatial layouts, and interaction modes, resulting in an interactive technology exhibition providing visitors with rich tangible learning experiences as most effective learning devices as demonstrated by previous studies (Gewers et al., 2021, Krestanova et al., 2021, Bobbe et al., 2022).

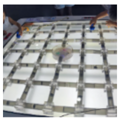
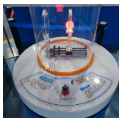
4. Design Process

4.1. CASE STUDY

We visited and observed several core technology museums in Shenzhen, a prominent city in China, and recorded some popular exhibits. We conducted a detailed analysis of these exhibits based on the following dimensions: exhibit name, exhibit theme, exhibit description, classification of exhibit size, presence and form of labels, simultaneous operation capacity, maximum group visit capacity, the audience participation mode, necessity of cooperation with others, possibility and nature of contact with exhibits, duration of participation and interaction, lighting effects and sounds. Some dimensions are strongly correlated, such as classification of exhibit size and simultaneous operation capacity. Table 1 lists 10 classic cases selected for collation, which basically cover all the main features of the findings. To make the table more concise, we used abbreviated forms of these feature descriptions.

We found that popular exhibits usually engage children for 60~180 seconds and feature touchable operation, mechanical buttons, manual touch and responsive lights and graphic operation instructions. Similarly, comparing these observations with 40 technology products found on the internet resulted in a very consistent match. Therefore, when designing exhibits, we can deeply integrate these characteristics to provide visitors with exhibits that are sufficiently attractive. Through the thorough understanding of the public's concern for the development of technology and their demand for the characteristics of exhibits, we know that most of the existing exhibits only reflect basic scientific principles, while those close to practical applications are rare. Therefore, we turn our attention to energy storage batteries, especially the key material - graphene. Graphene plays a crucial role in batteries, and has enormous application potential due to its unique physical characteristics. Next, we will explore in detail the design of exhibits based on energy storage batteries, demonstrating the important application of graphene in the charging and discharging process of energy storage batteries, and describing the interaction process between visitors and exhibits.

Table 1. 10 exhibits selected from cases

Exhibits					
Name	Recognize lock	Maze	Wireless charging	Zodiac signs	Robot fish
Label form	TGO	GO	GO	TO&GO	NO
Participatory modalities	EM	EP	EM	EM	OD
Contact form	TP	MB&TP	HR	MB	TP
Interaction time	IE	IE	PE	LIE	NI
Light effect	NL	NL	LD	LP	NL
Exhibits					
Name	Cross river	Carbon footprint	Chromatic mirror	Deformed metal	Little racer
Label form	STG	TGO	TGO	NO	STG
Participatory modalities	EP	OS	BR	OD	OD
Contact form	FP	MB&STG	EM	MB	VC
Interaction time	IE	IE	WE	OP	LIE
Light effect	LP	NO	LD	NL	NL

(Label forms can be divided into (NO) No Operation Label, (TO) Text Operation Instructions, (GO) Graphics Operation Instructions, (TGO) Text Guidance Operation Instructions, and (STG) Screen Step Guidance Instructions. Participation modes can be divided into (OS) Observation - Static Display, (OD) Observation - Dynamic Display, (EM) Experience - Manual Exploration, and (EP) Experience - Physical Participation. Contact forms can be divided into (MB) Mechanical Buttons, (HR) Handwheel Rotation, (BR) Button Rotation, (TP) Touch Physical Entities, (ST) Screen Touch Operation, (VC) Virtual Contact, (FP) Foot Press Pressure Contact, and (NC) No Contact. Interaction time can be divided into (OP) Observation Processes Requiring 0~15 Seconds, (NI) Not Interested 0~15 Seconds, (WE) Watching Experience 15~30 Seconds, (PE) Perception Experience 30~60 Seconds, (IE) Investment Experience 60~180 Seconds, and (LIE) Long-Term Investment Experience 180 Seconds or More. Lighting effects can be divided into (NL) No Lighting Effect, (LP) Lighting as a Prompting Effect, and (LD) Lighting Display Results.)

4.2. PRINCIPAL STRUCTURE OF THE BATTERY

The rapidly developing new energy storage industry has seen the dominance of lithium iron phosphate ($LiFePO_4$) batteries as the preferred choice for both power and energy storage applications. Despite their intricate internal structure and the various chemical reactions involved in charging process and discharging process, we have simplified their design for easier understanding by nonexperts, laying the foundation for broader applications and market acceptance. The three-dimensional crystal structure of $LiFePO_4$ is shown in Figure 1. The parallel planar layers formed by FeO_6 are connected by PO_4 tetrahedrons (each PO_4 has one common point with one FeO_6 layer, and another FeO_6 layer has one common side and one common point), and there is no connection between PO_4 (Ramasubramanian et al., 2022). This special structure also provides a very interesting reference for the design of the exhibit model later.

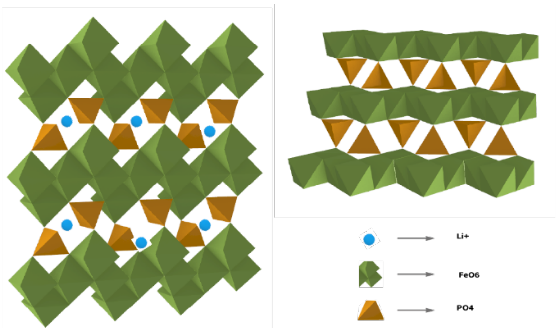


Figure 1. Lattice structure of $LiFePO_4$

In the past decade alone, the energy density of these batteries has doubled while their cost has been reduced by a factor of four. The role of graphene in the anode cannot be ignored. Figure 2 shows two different mechanisms for the formation of compounds between graphene layers as a source of inspiration for design (Borah et al., 2020).

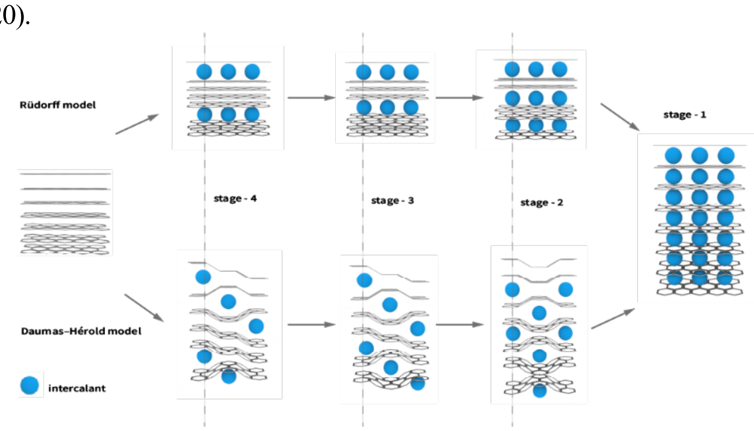


Figure 2. two different mechanisms for the formation of compounds between graphene layers

4.3. INTERACTIVE ILLUSTRATION

According to the internal structure of the energy storage battery, we have carried out a series of interactive operation design, so that visitors can acquire knowledge and experience in the process of observation and hands-on operation. We simplify the model of the battery to only include the cathode, separator, anode, and the lithium ions (Li^+) flowing within the battery. By determining the direction of electron flow, we can deduce the direction of current flow which is opposite to the direction of electron flow, indicating whether the battery is being charged or discharged (Zhang et al., 2023). The specific interactive operation and effect are as follows.

4.3.1. Understanding the structural characteristics of materials

As shown in Figure 3, the graphene plate can be pulled out for observation and touch, which is equivalent to a switch, and its shape can be changed. When the graphene plate is pulled out, the exhibit will remain inactive. Conversely, when the graphene plate is pushed back to the right position, it is equivalent to the switch closing, indicating that the battery package has been completed, so that subsequent operations can be performed.

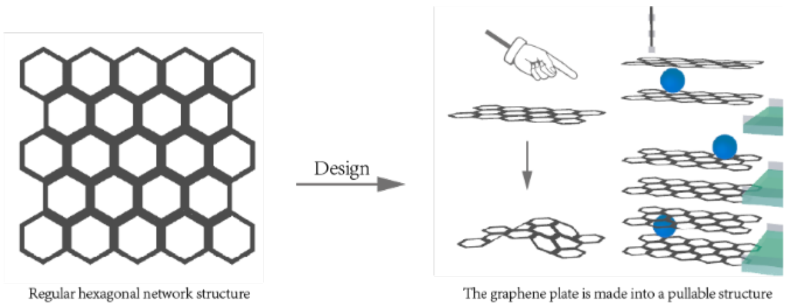


Figure 3. Understanding the structural characteristics of graphene by touching and observing

4.3.2. Learning charging process from the interaction

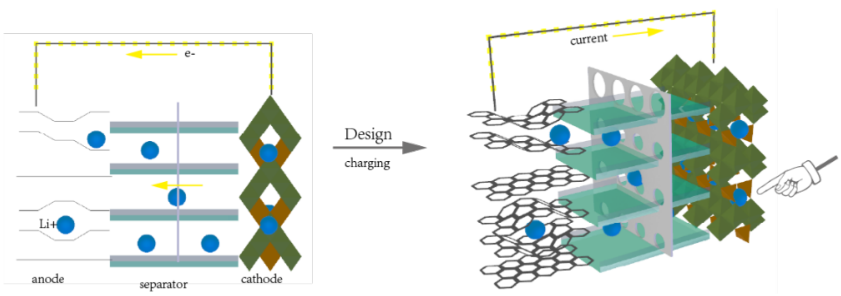


Figure 4. Charging process (Li^+ flow from the cathode to the anode, and electrons flow from the cathode to the anode through the external power supply.)

As shown in Figure 4, the blue sphere represents Li^+, and the LED light band represents the flow state of electrons. Currently, the battery is connected to an external power supply. When the cathode does not have movable Li^+ spheres, the indicator shows 'fully charged'. When the cathode has movable Li^+ spheres, the visitor can use his finger to move the sphere through the pores in the separator and roll to the opposite anode position to stop. The indicator shows 'in charging'.

4.3.3. Learning discharging process from the interaction

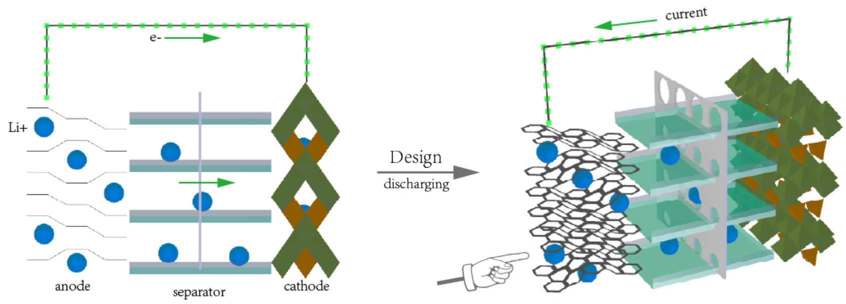


Figure 5. Discharging process (Li^+ flow from the anode to the cathode, and electrons flow from the anode to the cathode through the external electrical load.)

As shown in Figure 5, the blue sphere represents Li^+, and the LED light band represents the flow state of electrons. Currently, the battery is connected to an external electrical load. When the anode does not have movable Li^+ spheres, the visitor can use his finger to move the sphere through the pores in the separator and roll to the opposite anode position to stop. The indicator shows 'discharging in process'.

5. Conclusion

Based on in-depth field research, systematic data analysis, and the integration of multisensory design elements, we propose an interactive exhibit centred around a graphene-based energy storage battery model. Throughout the design process, we leveraged the expertise of every team member in developing the exhibition piece with various disciplinary perspectives and employing diverse methodologies. The aim of the proposed exhibition piece is to enable visitors to understand the two-dimensional structure and flexible properties of graphene through a spatial sensory experience that enables visitors to visually perceive the charging and discharging processes and interact by manually triggering the movement of lithium ions. In doing so, visitors can gain a deeper understanding of the operational mechanisms of materially mediated electricity, upon which we rely on daily.

Our design experience has shown that interdisciplinary collaborative teams are required to effectively integrate the unique properties of graphene into a spatial interactive exhibit. We posit that beyond this exhibit design, these remarkable materials, which serve as the foundation of technological advancement, hold vast potential for further exploration in the field of exhibition design. Future challenges in streamlining similar design-focused interdisciplinary collaboration processes include the establishment effective communication mechanisms and cross-disciplinary vocabulary, the achievement of data diversification and sharing, and the integration of different methodologies and data into interdisciplinary models. Translating initial design concepts into viable exhibition design remains a significant task.

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