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Guidelines for Enhancing the Learning Environment by the Integration of Design Flexibility and Immersive Technology (The Case of the British University in Egypt's Classrooms)

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Abstract
The trend towards developing the space and technology in educational institutions is crucial for enhancing the learning environment. According to Basdogan & Morrone (2021), there is a lack of flexible learning spaces that accommodate all changes, educational needs, and technological development. This study aimed to develop guidelines for enhancing learning environment by the integration of design flexibility and immersive technology. The study adopted mixed method approach: qualitative and quantitative methods, integrating the theoretical study of the flexible learning spaces design and immersive technology literature review into the applied study of proposing flexible technological learning space in the British university in Egypt. Study findings determined the incapability of traditional learning spaces to adapt with all users needs in comparison to the proposed flexible technological learning space. The study concluded with the proposed guidelines, the limitations and further study recommendations

Keywords: Flexibility; learning Space; learning Environment; Interior Design; Immersive Technology.

1. Introduction

The flexibility of design is defined as the ability to change its internal structure of a space to accommodate different needs. Mainly, flexibility in interior design related to the space design elements and components. Those properties depend on the physical shape in addition to its compositional and structural characteristics. Geometrical properties can be transformed to gain a flexible space used for a variety of purposes on the same plot of land(Abdulqader et al., 2014).
Immersive technology is a terminology that refers to the technologies that merge between digital world and physical world. These technologies are: Virtual reality (VR), Augment reality (AR), and Mixed reality (MR). Obviously, Architecture education has been revolutionized by immersive technology, providing students with opportunities to interact dynamically and interactively with their pedagogical contents. (teaching paper source)
This study intended to examine the role of design flexibility and immersive technology in learning environment enhancement. It included discussion and analysis concerning design flexibility and immersive technology through adopting mixed method approach, combining both qualitative and quantitative methods. The study contributed in representing the influence of development of both technology and space on the learning environment.

1.1. Research problem

Innovative learning environment has four main parameters which they are: space, pedagogy, technology, and users(Basdogan & Morrone, 2021). It has been stated that the space is the most affectable element on the learning environment which followed by the technology (Afara et al., 2024; Amen et al., 2024). It has been examined that enhancing interior design of learning space and improving the technology used will increase the efficiency of the learning environment. Hence, the focus on developing learning environment space and technology became crucial. It has been stated that there is a Lack of flexible technological learning spaces that accommodate all changes, educational needs, and technological development (Basdogan & Morrone, 2021).

1.2. Research questions

1-How could the combination of flexibility and immersive technology enhance the optimization of learning spaces?
2-What are the design elements of flexible learning spaces that impact their efficiency?
3-What is the role of immersive technology in education?

1.3. Research Aim and Objectives

Develop Guidelines for Enhancing the learning environment by the integration of Design flexibility and immersive technology in the field of architecture education.

1. Analyse the flexible design elements and requirements ,and classrooms case studies
2. Determine the Immersive technologies applications in education
3.

1.4. Research hypothesis

This research paper has claimed that the learning environment will be enhanced by the integration of the concept of design flexibility and immersive technology.

1.5. Research methodology

Research paper has contained mainly theoretical study and applied study. Theoretical study discussed the literature review about the flexible learning spaces design, immersive technology aspects and their relation to each other, reaching to the literature review output which was the preliminary guidelines that derived from the impact of flexible design and the role immersive technology in the education combination.

The applied study has analysed case studies of traditional learning spaces that have been transformed to flexible technological learning spaces. In addition, a field study has been conducted and analysed for testing the preliminary the guidelines, Examining the limitations, modifications, and the research final guidelines.

2. Literature Review

The theoretical study has reviewed comprehensive discussion of existing research papers on the flexible learning spaces and the immersive technology role in education.

Previous researches have obtained many approaches for the role of flexibility in the learning environment. A study by ministry of education (2016), has determined that the main elements reflect flexibility in space are furniture and walls. A study by Hanbury (2020) has obtained multiple recommendations for flexible learning spaces prototypes, as shown in figure 1.

A study by Abdulqader et al.(2014), has shown that the flexibility as physical property could be reflected on furniture design. It has been recommended flexible shapes for tables design in classroom, as it shown in figure.2.In addition, The study has discussed the importance of following specific design guidelines for the flexibility. It has been obtained the main design element for the flexible learning space, as shown in table.1.

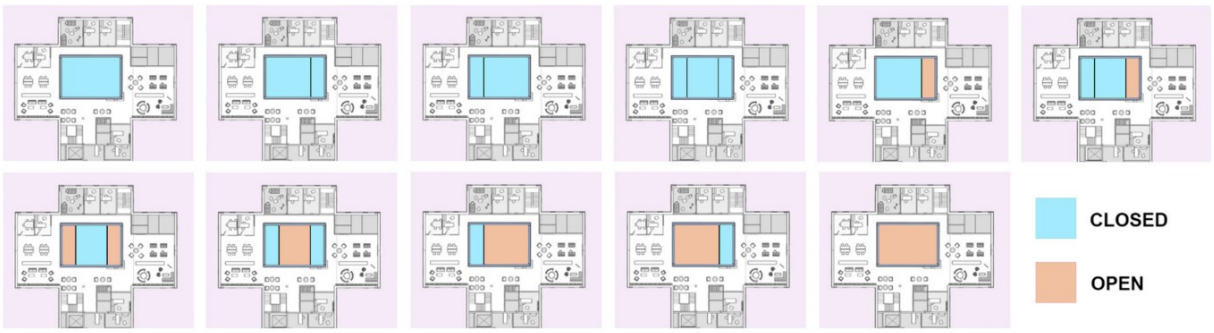


Figure 1. Flexible learning dpaces prototypes (Hanbury,2020)

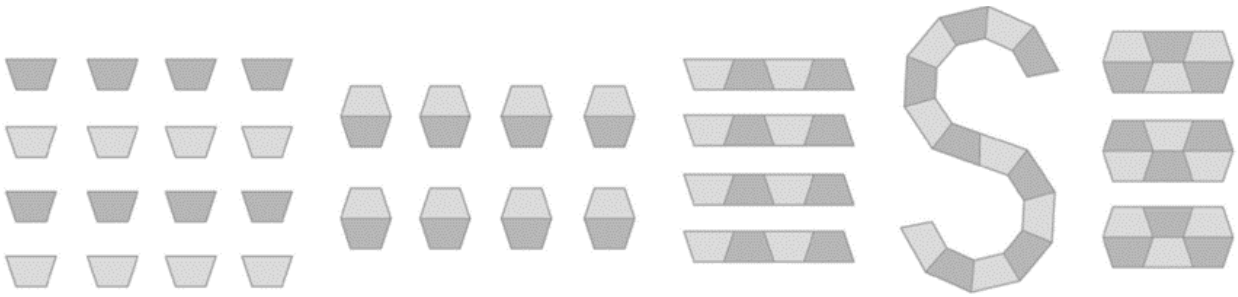


Figure 2. Flexible shapes for tables design in classroom (Abdulqader et al.,2014)

Table 1. Flexible learning space Design elements (Abdulqader et al.,2014)

Flexible learning space Design elements						
Colour	Form	Light	Line	Pattern	Texture	Space
	 Shallow Rectangle  Deep rectangle	 Window Skylight Atrium  Side Upward Downward	vertical (up-and-down) horizontal (side-to-side)  Dynamic (express motion)	No specific pattern (according to the design)	No specific texture (according to the design)	 Fixed+movable walls  Plain smooth flooring  Suspended ceilin with different lighting options  Movable flexible designed furniture

literature review provided an overview of existing research on the applications, benefits, challenges, and implications of immersive technology in educational settings. Immersive technology has been defined as the Integration of virtual content with the physical environment allowing the user to engage naturally with blended reality (Amen & Nia, 2020; Aziz Amen, 2022 ; Auwalu & Bello, 2023; Gaha, 2023). There are main types of immersive technology are: Virtual reality (VR), mixed reality and augmented reality(AR).Virtual reality (VR) is a computer-generated simulation of a three-dimensional environment that users are able to engage and interact to experience a sense of presence and fully immersed in the virtual world through specialized hardware, including gloves or headsets.Augmented reality (AR) is an interactive experience that overlays digital information by overlaying digital information, such as3D models, images, or videos,onto the real world in real-time using devices like AR glasses, smartphones,or tablets.Mixed reality (MR) is the combination between both augmented reality and virtual reality, that allows physical and digital objects to interact in real-time within one immersive environment. This allows users to manipulate and interact with virtual objects while still being aware of the real world around them (Slater et al.,1997).

Immersive technology has recorded a significant contribution in the education. A study by Kuhail et al. (2022) has summarized the role of immersive technology in education, as shown in table.2.

Table 2. Immersive technology role in education (Kuhail et al.,2022)

	Not identified (active)	Experimental learning	Self-directed learning	Collaborative learning	Inquiry-based learning	Project-based learning	Game-based learning	Inquiry-based learning	Virtual reality				Augmented reality				Mixed reality			
									Touch	hardware	Hand	Head	Touch	hardware	Hand	Head	Touch Head		Hand	Head
Augmentation	✓	✓	✓	✓	✓	✓	✓	✓									✓	✓	✓	
Modification	✓	✓	✓		✓	✓							✓	✓	✓	✓				
Redefinition										✓	✓	✓		✓		✓		✓	✓	✓
Substitution			✓	✓	✓	✓				✓	✓			✓	✓				✓	
	✓	✓	✓	✓	✓	✓	✓	✓												

To conclude, literature review has highlited previous research approaches of both flexibility in learning spaces and immersive technology role in education.The learning spaces have impacted by the usage of immersive technologies, so there are spatial insights to design the learning space. The following table has summurized the spatial design recommendations to design flexible technological learning space.

Table 3. Spatial design arrangment recommendations (Developed by Author,2024)

spatial design arrangement recommendations														
Walls		Flooring				Ceiling		Equipment			Furniture		
Fixed	Moveable	Tiles	Plain	Rugs	Grains	Suspended	Non-suspended	Fixed	Partially fixed	Portable	Fixed	Folded	Moveable
✓	✓		✓			✓		✓	✓	✓		✓	✓

3.Applied Study

The study adopted mixed methods that included qualitative, quantitative, experimental and case study strategies. The applied study has incorporated both anylatical study and experimental study. The anylatical study involved case studies analysis. Experimental study involved transformational field study on traditional learning spaces of the British university in Egypt.

3.1.Case Studies Analysis

This paper has analysed two case studies for international learning spaces that have been transformed from traditional to flexible technological learning space. The following diagrams show these case studies analysis.

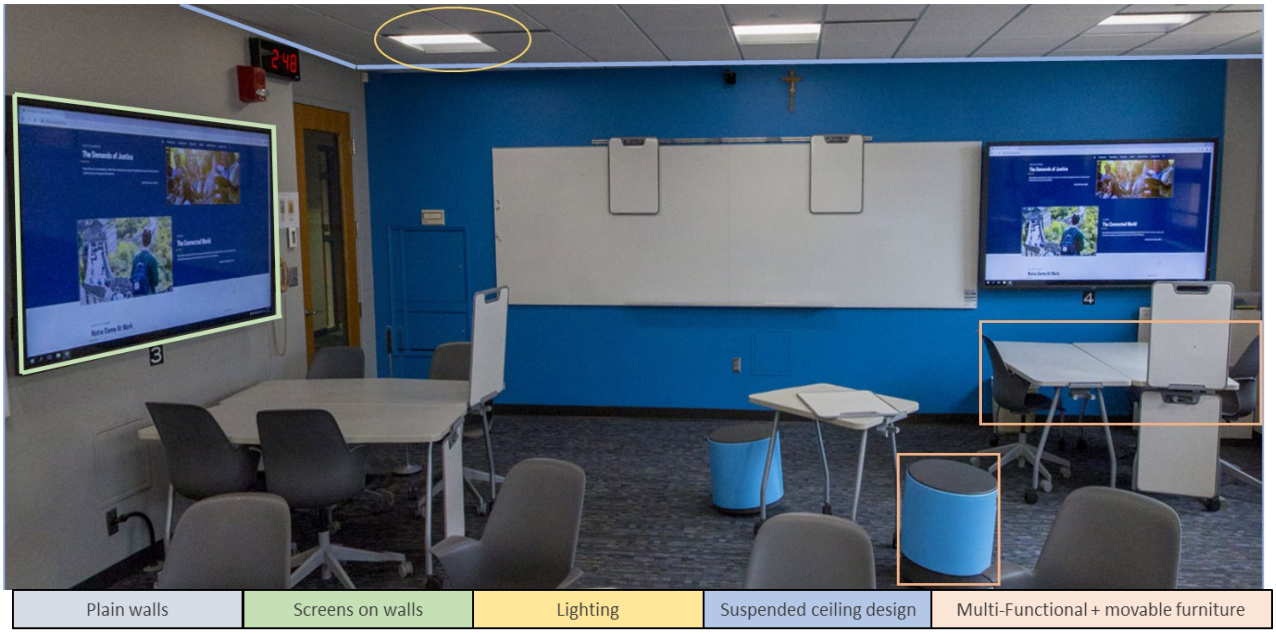


Figure 3. Notre Dame classroom in Indiana, USA analysis (Developed by Author, 2024)

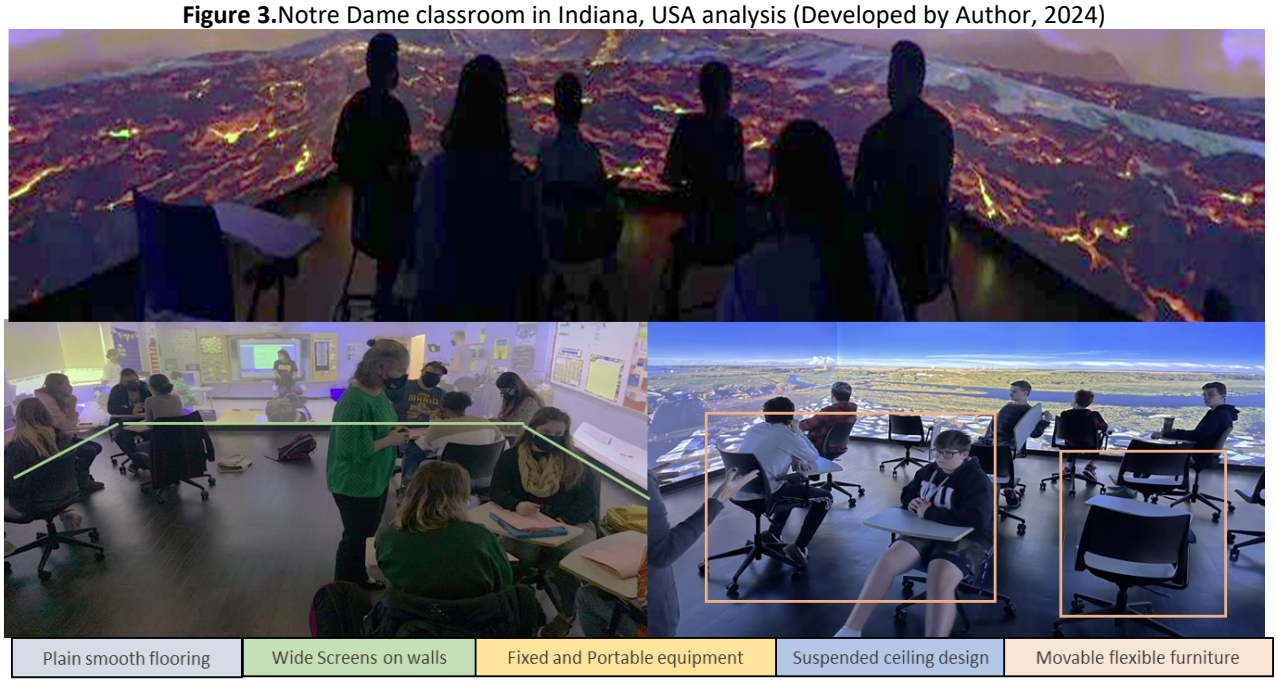


Figure 4. Immersive Learning Centre,Lehigh university in Benthlem,USA analysis **(**Developed by Author, 2024)

A comparative study has been conducted between each case study's traditional status and flexible technological status. It summarized the strengths and limitations of each approach and identify best practices for designing innovative educational environments. The following tables highlight the importance of designing innovative educational environments that prioritize student-centered pedagogies, active learning experiences, and seamless integration of technology.

Table 4. Notre Dam classroom comparative analysis (Developed by Author, 2024)

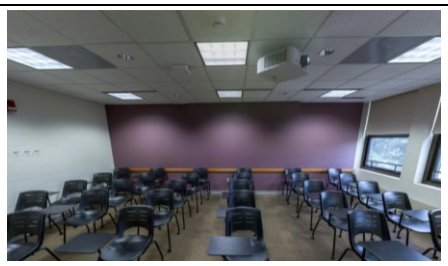
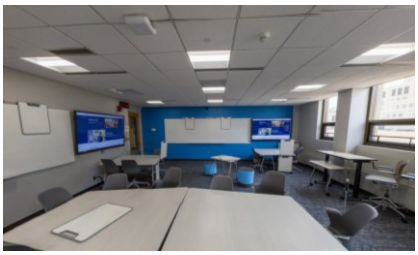
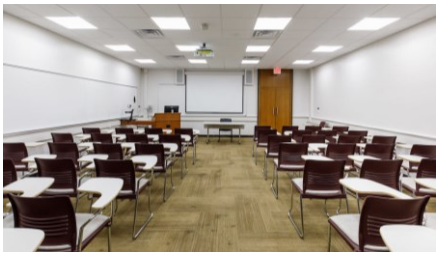
Notre Dam classroom comparative analysis		
	Traditional classroom	Transformed Contemporary prototype
Figure		
Occupancy	17.7 square foot per student	32.33 square foot per student
Furniture	rolling single tablet armchairs	flexible tables (1-5 person) and chairs
Technology	single projector 1 chalkboard	4 LCD screens 3 marker boards and 30 huddle boards
zone	1 fixed teaching zone	4 flexible learning zones

Table 5. Lehigh university comparative analysis (Developed by Author, 2024)

Lehigh university comparative analysis		
	Traditional classroom	Transformed Contemporary prototype
Figure		
Occupancy	35 student	20 student
Furniture	rolling single tablet armchairs	flexible tables (1-5 person) and chairs
Technology	single projector 1 chalkboard	4 sided screens
zone	1 fixed teaching zone	4 flexible learning zones

Case studies analysis has highlighted the potential benefits of transforming traditional to flexible technological learning spaces. The analysis has reflected that the integration of a group of flexible design elements and technological approaches to the learning space improved its efficiency as a learning environment.

3.1. Experimental Field Study

The field study has investigated the effectiveness of designing learning environments that prioritize design flexibility and immersive technology. The study aimed to transform a traditional learning space in the British university in Egypt to a flexible technological learning space by implementing the design aspects that have been analysed and discussed previously. A classroom in the university has been chosen to be observed, analysed, redesigned and transformed to be adapdable with different learning activities. The field study conduction has followed a group of procedures and steps. Mainly, the procedures covered data collection, pre-design, design, equipment & furniture preparation, implementation, results and evaluation.

Experimental design: a classroom in the British university in Egypt has been selected to redesign it by implementing flexible design and immersive technology techniques. Two types of learning activities has been chosen to test the space flexibility ability of changing its function. The recommended prototype has been designed to test the easy change in delivery learning activity to display learning activity.

Field study Selection criteria : BUE classroom has been selected to conduct the field study, because of being a national learning space, its data availability and implementation opportunity.

Data collection: Basic tools and instruments were used to collect data about the targted learning space. A mesurment tape has been used to observe the classroom dimensions and appliances allocations. Graph sheets and pencils needed to document the acutal state of the classroom and user analysis.

Participants: Purposive non-random sampling used to select a group of 12 designer, tutors, and lecturers have been selected to evaluate the proposed design according to aspects mentioned in literature review and case studies.

Data analysis: It involved multiple types of analysis such as: qualitative, quantitative, comparative analysis and visualization. Softwares such as sketchup and twinmotion have been used for classroom recommended prototype visualization and analysis.micrisoft office used for the comparative analysis between the current traditional classroom and the proposed flexible technological one. In addition, data reduction and presentation techniques are crucial to simplify data in a clear and useful way, aid researchers in communicating and summarising the key outcomes of their data study.

limitations: Acknowledging limitations is important for interpreting the findings of the study accurately and responsibly. This study has faced several challenges and limitations such as:

1-Limited number of case studies

2- Time: this study needed a plenty of time to discuss and analyse all aspects

3- Cost and budget: it was very expensive to transform a learning space in real life, so the study was limited to a virtual design and experts evaluation

4- Lack of researches that contain both flexibility in design and technology usage as dependent variables, and learning environment enhancement as an independent variable.

Procedures: A research study's procedures section described the particular steps and approaches used to fulfil the study's goals and provide answers to its research questions.

1- The experiment began by observation of the existing classroom dimensions using Meter tape and graph sheets

Figure 5.BUE Classroom observation (Developed by Author, 2024)

2- The dimension used to model the learning space digitally using Sketchup, representing both delivery and display learning activites in the current state.

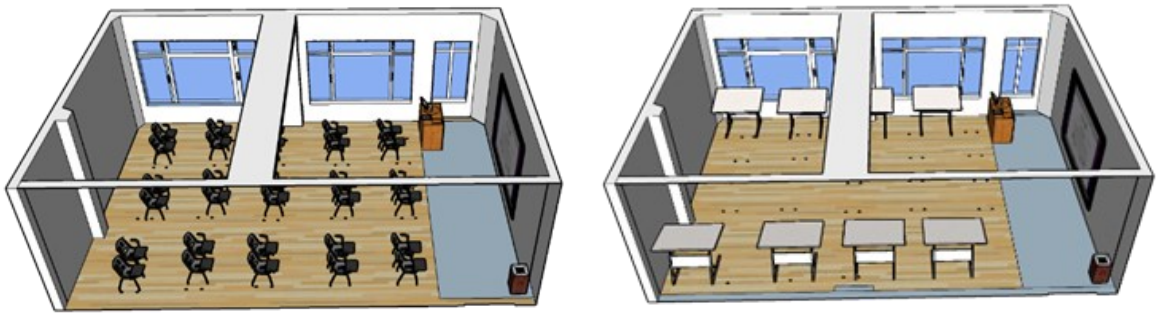


Figure 6. Sketchup model of the current state of the learning space at BUE (Developed by Author, 2024)

3- The design has been developed according to the preliminary guidelines of literature review and case studies conclusion.

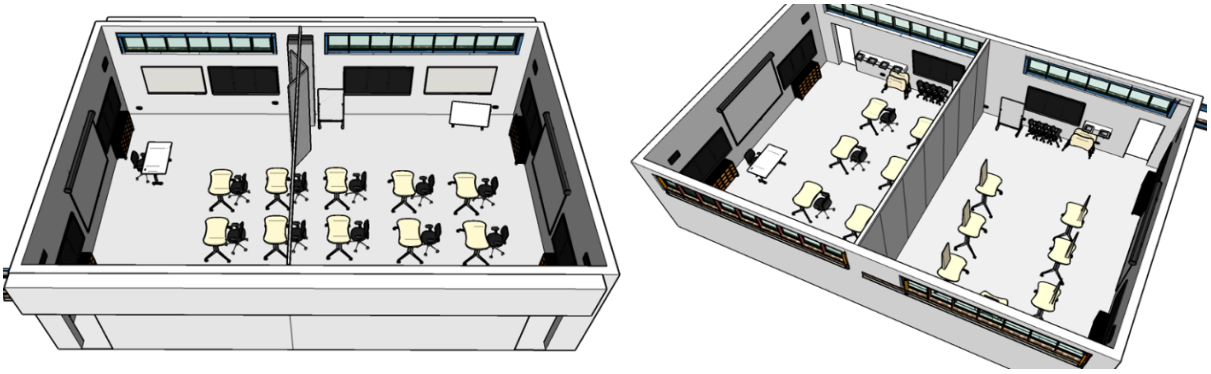


Figure 7. Developed model on sketchup (Developed by Author, 2024)

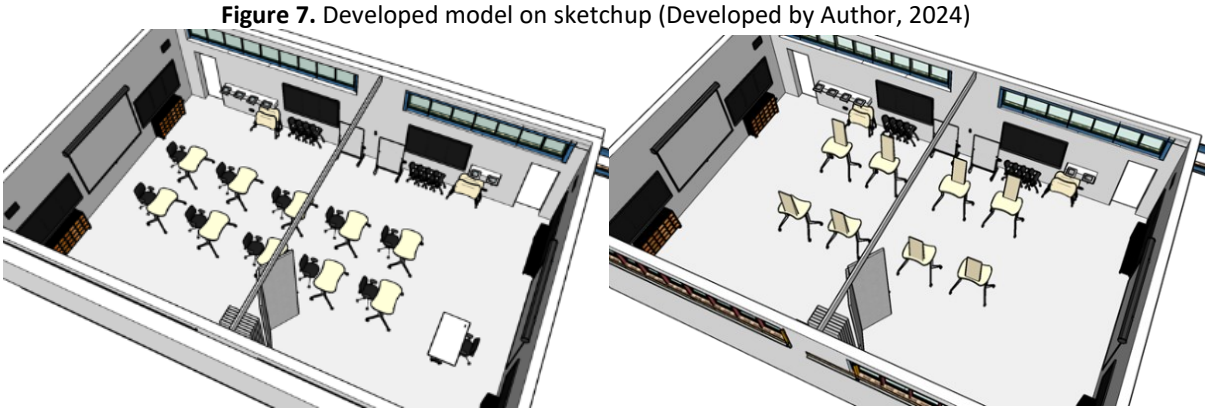


Figure 8. Representation of classroom design in display and delivery actitvities (Developed by Author, 2024)

4- Implementation: it was very difficult to implement the proposed prototype in real life, because of time and high cost limitations.

5- Design evaluation: it has been conducted through two main methods: research questionnaire and comparative analysis.A survey questionnaire about the proposed classroom prototype has been provided to the group of interior designers and tutors.They were asked to answer questions about: Age, Occupation, Year of experience, learning space general info,flexible learning space design elements, immersive technology design requirements and
the proposed design predicted functionality and efficiency.

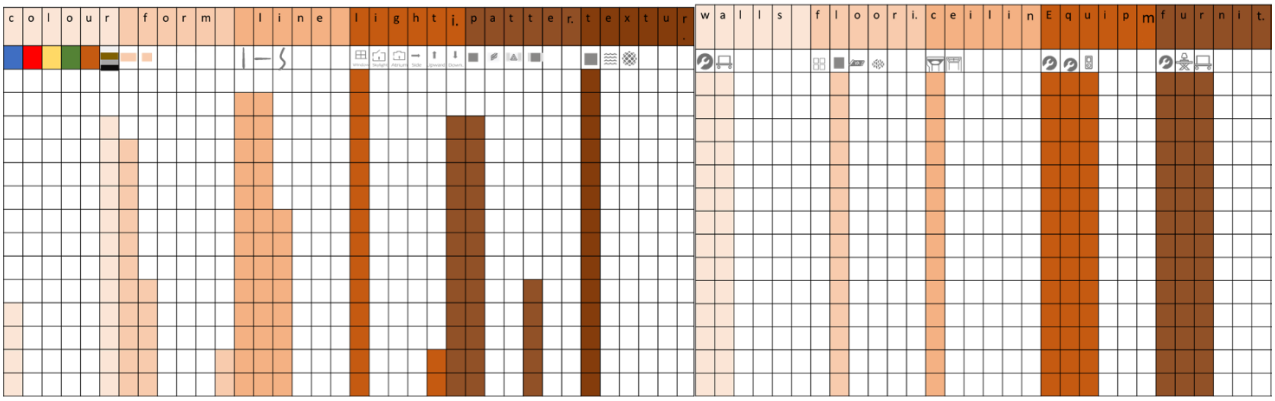
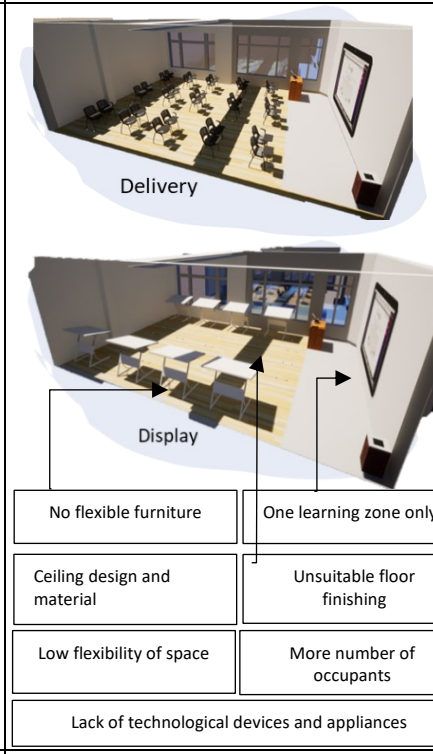
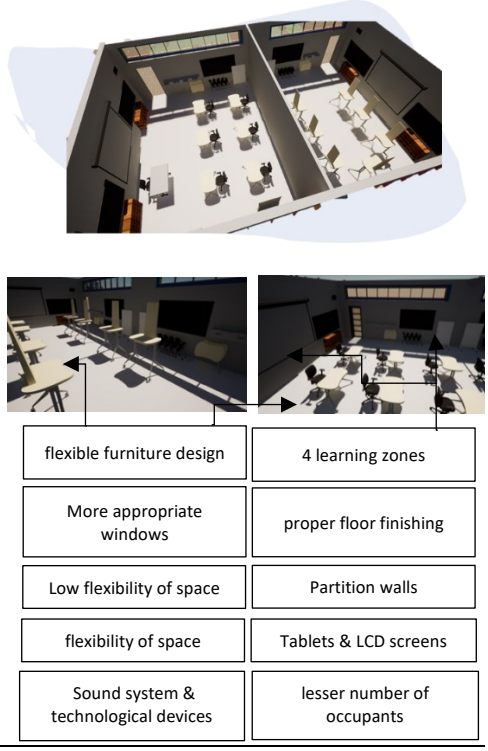


Figure 9. Summary of main aspects of evaluation questionnaire (Developed by Author, 2024)

A comparative analysis between the traditional current state of the BUE classroom and the proposed flexible technological prototype has been conducted to identify similarities, differences, strengths, weaknesses, and patterns.In addition to hightlight the main advantages and disadvantages of transforming the classroom. They have been compared with respect to many aspects, as shown in the following table.

Table 6. Comparative analysis between the traditional current state of the BUE classroom and the proposed flexible technological prototype (Developed by Author, 2024)

	Current state of BUE classroom	**proposed flexible technological prototype**
Figure		
Cost	Lower initial cost	Higher initial cost
Changing ability	Difficult ability to change functions	Easy ability to change functions
Changing time	Long time for changing functions	short time for changing functions
Changing effort	More effort for changing functions	less effort for changing functions
Technological adaptability	Could not adapt to all technological development	Could adapt to all technological development
Technological appliances capacity	Could not adopt many of technological appliances	Could adopt many of technological appliances
Flexibility	Low flexibility of movement through the space	Flexibility of movement through the space

6-Interpret Findings: interpret the results of previous data analysis that will lead draw the final conclusion.summurizing the study final outputs provide key insights to determine the final guidlelines. It provides the pre-final steps before the final guidelines by referring to the aspects that need to be: kept, developed and added.
7- Final proposal: update the designed learning space with the aspects need development and addition, then provide the final proposed prototype
8- Final guidelines: develop the final guidelines that refer to the main research aim.

4.Results and Findings

The results and findings of both theoretical and applied study for "Guidelines for Enhancing the learning environment by the integration of design flexibility and immersive technology" reveal several key insights into the impact of these approaches on the learning experience. Determination of the results and findings of the study highlights the next step of the guidelines development. Research findings determine that there are many aspects need to be developed, kept or added. The following table shows all the studied aspects related to both variables of flexbile design and immersive technology.

Table 7. Study results and findings (Developed by Author, 2024)

Aspects		To be kept	To be Developed	To be Added
Flexible learning space design elements	Color	Neutral colours	No specific development is mentioned for colours.	Setting up a group of colours by augmented reality as an option to be changed
	Form	Rectangular form	No specific development is mentioned for the forms.	No specific addition is mentioned for the forms.
	Lighting	Natural lighting: windows Artificial lighting: downward type	Windows design could be developed to be designed as high windows	Artificial side lighting could be added.
	Line	All types of lines	No specific development is mentioned for the lines.	No specific addition is mentioned for the lines.
	Pattern	Plain pattern is best option for all functions	No specific development is mentioned for the pattern.	No specific addition is mentioned for the pattern.
	Texture	Smooth texture	No specific development is mentioned for the texture.	No specific addition is mentioned for the texture.
Immersive technology design requirements	Walls	The main partition walls	Sound insulation should be added to the partitions	Free movement partitions could be added
	Flooring	Plain flooring	Maybe developed as raised floor	No specific addition is mentioned for the flooring.
	Ceiling	Suspended ceiling should be kept	No specific development is mentioned for the ceiling.	No specific addition is mentioned for the ceiling.
	Equipment	Headsets Tablets Smart glasses Remote controls	LCD screens should be developed to be touch screen and have a cover with the same colour of walls	No specific addition is mentioned for the equipment.
	Furniture	All items should be kept	No specific development is mentioned for the furniture .	No specific addition is mentioned for the furniture.

5. Discussions

The research findings discussion considered as a critical reflection on the significance outcomes of the study. The study findings examined the needed modifications to the proposed prototype design. It lead to the last step of developing the research guidelines. The following figure has shown the final proposal of the British university in Egypt classroom as a flexible technological learning space.

Figure 10. Final prototype proposal of BUE classroom (Developed by Author, 2024)

The proposed classroom contained many innovative design and technological elements. It has been designed to assess all the learning activities, be flexible in transformation, and adapt with the future needs. The following figures has illustrated all the developed design elements and technological innovations.

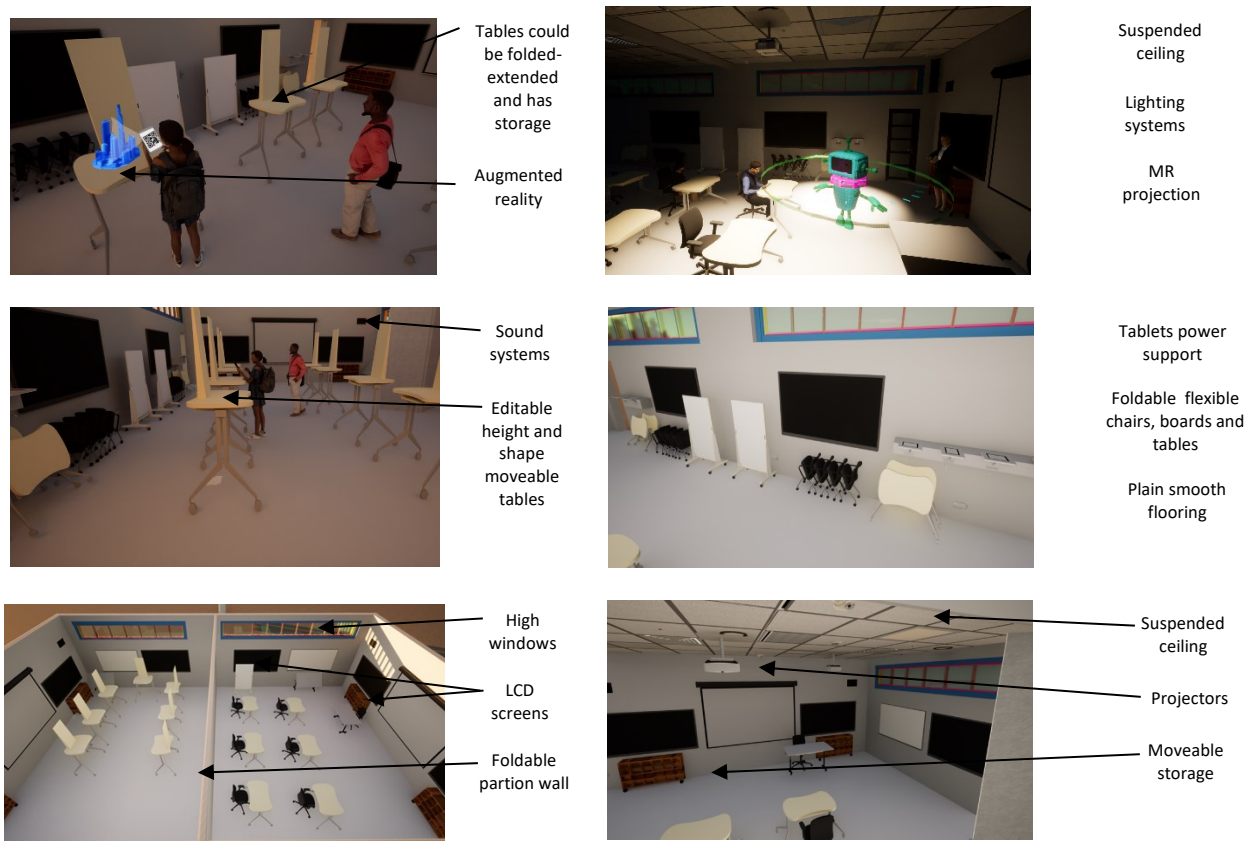


Figure 11. proposed classroom analysis (Developed by Author, 2024)

6. Conclusion and Recommendations

In conclusion, The study has demonstrated how using immersive technology and design flexibility can significantly enhance the learning environment. It has been observed that integrating immersive technology and design flexibility significantly enhances educational environments. Flexible technological learning environments provide students with opportunities for personalized experiences, active learning, and peer-to-peer interaction, leading to improved learning outcomes and performance. The study has been concluded with the final guidelines that could be followed for Enhancing the Learning Environment by the Integration of Design Flexibility and Immersive Technology. The following table summarized these guidelines.

Table 8. The final guidleines of the study (developed by Author,2024)

Guidelines for enhancing the learning environment by the integration of design flexibility and immersive technology		
Flexible learning space		
Colour	Neutral colors	Using neutral colours for the basic design of walls and space interior, as it will suitable for all functions
Form	Shallow rectangle	Using shallow rectangle for the basic design of walls and space interior, as it will suitable for all functions and all changes
lighting	Natural: Window Artificial: Side, downward	- Using high window with covering panels as a source of natural lighting - Side and downward types of artificial lighting are the proper choice for all activities
Line	vertical (up-and-down), horizontal (side-to-side), dynamic (express motion)	all types of lines could be used in the design of space
pattern	Plain, Minimal	Using minimal and plain patterns could adapt with any change and functions
Texture	Smooth	Using smooth textures in the design will ease many of design or furniture implementation in the space

Immersive technology design usage			
Augmentation	AR	Touch	Marker-Based and marker-less
		Hardware	Advanced HDM
		Hand	HDM-based and Cave, portable devices
		Head	_____
Modification	MR	Touch	Projection based, hand control
		Hardware	HDM based and enhanced technique
		Hand	HDM-based and Cave, hand control
		Head	Advanced HDM , head sets
Redefinition	VR	Touch	Projection based, hand control
		Hardware	HDM based and enhanced technique
		Hand	HDM-based and Cave, hand control
		Head	Advanced HDM , head sets
Redefinition	MR	Touch	_____
		Hardware	HDM based and enhanced technique
		Hand	_____
		Head	Advanced HDM , head sets
Redefinition	AR	Touch	_____
		Hardware	_____
		Hand	HDM-based and Cave, hand control
		Head	_____
Substitution	VR	Touch	_____
		Hardware	_____
		Hand	HDM-based and Cave, hand control
		Head	_____
Substitution	MR	Touch	_____
		Hardware	HDM based and enhanced technique
		Hand	HDM-based and Cave, hand control
		Head	_____
Substitution	MR	Touch	_____
		Hardware	_____
		Hand	Advanced HDM , head sets
		Head	HDM-based and Cave, hand control

Spatial arrangement		
Walls	Fixed	The main four sided walls of the space need to be built and fixed
	Moveable	Moveable partitions need to be included in the design, to separate the space when it needed
	_____	_____
Flooring	plain	Moveable partitions need to be included in the design, to separate the space when we need
	_____	_____
	_____	_____
Ceiling	Suspended	Acoustic suspended ceiling, to contain ventilation and lighting equipment
	_____	_____
	_____	_____
Equipment	Fixed	Projectors on ceiling and AR devices
	Partially fixed	Screens on walls
	Portable	Headsets, portable remote control
Furniture	Fixed	Digital boards on all sides of the room
	Folded	Table, chairs, white boards and storage areas
	Moveable	Table, chairs, and storage areas

Based on the study gaps and limitations that have been mentioned, there is a group of recommendations has been provided to develop this study in the future. The following point summarized the main recommended points:
1- use the literature review final matrix as a reference for testing the design for any of learning activity
2- it is recommended to develop this research in many other sectors such as: commercial, medical, recreational… etc., as the integration of the flexibility and the technological approach is very important to the future of these sectors interior spaces
3-According to the initial cost and time limitations, it is recommended for budgeting the application of the study:

Table 9. Budget recommendations (Developed by Author, 2024)

High budget	Intermediate budget	Low budget
Full transformation for design elements	Partially transformation of flexible design elements	Choose one or two elements of flexible design elements : such as tables in furniture
Full setup of smart immersive technology and appliances (shorter time)	Setup the main projectors, appliances, and consider the spatial interaction (intermediate time)	Consider the spatial interaction and the users use their own devices (longer time)

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Conflict of Interests
The Authors declare that there is no conflict of interest.

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