AMERICAN UNIVERSITY OF BEIRUT

DEVELOPING DESIGN STRATEGY FOR AN OPTIMAL SIMULATION CENTER-BASED PROGRAMME: THE AUBMC EXPERIENCE

by
CARLA TALAL DLEIKAN

A thesis
submitted in partial fulfillment of the requirements
for the degree of Master in Engineering Management
to the Department of Industrial Engineering and Management
of the Maroun Semaan Faculty of Engineering and Architecture
at the American University of Beirut

Beirut, Lebanon
April, 2019

AMERICAN UNIVERSITY OF BEIRUT

DEVELOPING DESIGN STRATEGY FOR AN OPTIMAL SIMULATON-CENTER BASED PROGRAMME: THE AUBMC EXPERIENCE

by

CARLA TALAL DLEIKAN

Approved by:

Dr. Selim Hani, Assistant Professor
Industrial Engineering and Management — Advisor

Dr. Bacel Maddah, Chairperson and Professor
Industrial Engineering and Management — Member of Committee

Dr. Saif Al-Qaisi, Assistant Professor
Industrial Engineering and Management — Member of Committee

Date of thesis defense: April 24, 2019

AMERICAN UNIVERSITY OF BEIRUT

THESIS, DISSERTATION, PROJECT RELEASE FORM

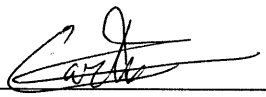
Student Name: Dleikan (Last) Carla (First) Talal (Middle)

☒ Master's Thesis ○ Master's Project ○ Doctoral Dissertation

☒ I authorize the American University of Beirut to: (a) reproduce hard or electronic copies of my thesis, dissertation, or project; (b) include such copies in the archives and digital repositories of the University; and (c) make freely available such copies to third parties for research or educational purposes.

☐ I authorize the American University of Beirut, to: (a) reproduce hard or electronic copies of it; (b) include such copies in the archives and digital repositories of the University; and (c) make freely available such copies to third parties for research or educational purposes after :

One ---- year from the date of submission of my thesis, dissertation, or project.
Two ---- years from the date of submission of my thesis, dissertation, or project.
Three ---- years from the date of submission of my thesis, dissertation, or project.



Signature

3 May, 2019

Date

ACKNOWLEDGMENTS

Firstly, I would like to express my sincere gratitude to my thesis advisor Professor Selim Hani, who has always been supportive and encouraging through my master's Research. He gave me great opportunity to meet knowledgeable and professional people working in the healthcare field.

I would also like to thank Dr. Rana Sharara- Chami and Zavi Lakissian, for their insightful comments and continuous monitoring and support. They gave me invaluable advices on my research. Besides, I need to thank the AUBMC (American University of Beirut Medical Center) and all the recruited participants who were involved in this study. They were very cooperative, and they offered me valuable information for my research. I have gained a great experience in healthcare and medical simulation because of such supportive professions around.

I am grateful to my committee Professors, Dr. Bacel Maddah and Dr. Saif Al-Qaisi for their contribution, guidance, insightful comments and encouraging words

Finally, I would like to thank my family and friends for believing in me and always providing unconditional support and love.

AN ABSTRACT OF THE THESIS OF

Carla Talal Dleikan for Master in Engineering Management
Major: Industrial Engineering and Management

Title: Developing Design Strategy for an Optimal Simulation Center-based Programme: The AUBMC Experience

Background: Simulation in healthcare has been developing a decade ago, it is an educational and training tool to improve both individual and teamwork skills. Medical simulation is applied in different settings; in-situ simulation in the actual real environment (clinics or emergency room) and off-site in simulation center-based hospital or university. Adopting simulation for learning and education needs a well design plan for the facility, other than the curricula and program plan. Designing and implementing a simulation facility is a complex and endeavor process, yet limited studies explore the design process of simulation facilities and provide official guidelines to achieve an optimal/ideal facility. Stakeholders at the AUBMC faced different constraints in planning and designing the new facility because there were no official guidelines to structure the layout, flow, and functions in the center, as well resources and personnel.

Objectives: This research aimed to (1) explore the design process for a simulation center-based hospital at the AUBMC, (2) identify the challenges of designing a simulation center in various institutions, and (3) identify a decision-making approach to plan for an optimal simulation center design.

Methods: This study was an exploratory case- study with multidimensional methods, qualitative and quantitative. On the bases of conducting semi-structured interviews with; personnel involved in the design process of the new AUBMC simulation center; and experts in the medical simulation field within the same institution and from other institutions in Lebanon. Besides, direct observations and documentation during the evolving of the process provided insights and understandings about the simulation operations and the design process.

Results: A total of 8 healthcare professions and experts in the simulation field, whose consent were secured, were included in the analysis. Participants involved in the design were from different industry sectors Biomedical Engineer, Architect, Computer Engineer, and Medicine. The majority of participants had experience in simulation between 5 and 10 years (50%). 2 simulation center and 2 labs were studied and explored, those

facilities' area range between 110 m^2 and 937 m^2, while the new center is 600 m^2. 2 facilities had a linear flow, 1 facility had a circular flow and the new center had a combination of circular flow and star shape. All studied facilities utilize multipurpose rooms with majority of 2 control rooms and 1 debriefing room.

According to the thematic analysis, 8 major themes were generated with categories and subcategories; administration with 3 categories, light with 2 categories, organization of space with 8 categories and 2 subcategories, equipment, design or current challenges, changes and constraints in design, ideality and optimality, recommendations and expectations.

The majority results conducted from participants involved in the design of the AUBMC simulation center; showed 8 key considerations for the structure and layout of the facility; circular flow, five multi-purpose simulation rooms, central control room, flexible and friendly working area, flexible debriefing rooms, administrative reception with waiting area, storage area, and utility rooms.

Conclusion: Findings from this study provide guidelines and key considerations for structuring the layout and flow of a simulation center, regardless of the size and space available. there is no one optimal or ideal space layout and design for a simulation center, there is "no one size/style fits all". Each simulation center structure and function adapt to the program needs and the project's goals. Additionally, this study provides both the design process flow and the decision-making approach; evidence-based design; to improve the architectural space while meeting end-users needs.

CONTENTS

ILLUSTRATIONS

TABLES

To My

Beloved Parents

and Friends

CHAPTER I

INTRODUCTION

A. Simulation in Aviation

Innovations in aviation simulation, resuscitation, and technology were crucial predecessors to medical simulation. In 1929, Edwin Link, the first flight simulator inventor, created a prototype “blue box” flight trainer because he believed that there is a safer, easier and less expensive way to learn and practice flying. In 1934, the army bought 6 Link trainers to develop training. During World War two, military needs encouraged Link to invent the “Celestial Navigation Trainer”, a “bomber crew trainer”, and “the first airplane specific model”. In the 1950s, flight simulation became more complex and real, after the birth of analog computers. In 1970, Singer merged with Link Aviation, to develop the hydraulic motion and visual systems, after improvements they designed a full flight simulation (Rosen, 2008).

Helmreich and colleagues (1999) mentioned that NASA was the first to describe crew resource management in 1979, and human factors are involved in most air safety problems. In the 1980s, Link/Singer Aviation created and manufactured a fleet of military flight simulators and the first submarine simulator (Strachan, 2000). In the 1990s, technical training for crew members were integrated into simulation, and not only focusing on individual training.

On the contrary, flight simulation was not a great tool for training according to some pilots, because it cannot replace a real aircraft. However, later analysis showed that simulator was effective for “training critical maneuver”, “technical skills” and “human factor skills” (Shappell et al., 2017). In the early 1980s, flight training focused on teaching and assessing individual pilot. In fact, two or more pilots might control the flight. The NTSB report shows 70% of flight accidents are not caused by the pilot’s technical skills, but 60 to 80% of accidents are caused by human error (Billings, 1984). After these investigations, the largest development was crew training and crew resource management.

B. Definition of Simulation

Medical simulation appeared at the end of the 20th century. The use of simulation in medical education grew frequently and it was an effective tool in healthcare education. Gaba defines simulation as “a technique, not a technology, to replace real experience with guided experiences that evoke substantial aspects of the real world in a fully interactive manner” (Gaba, 2004, p.1). Whereas, Jeffries (2005) added that “Simulation acts as activities that mimic reality of the clinical environment and designed to demonstrate procedures, decision making, and critical thinking through techniques as the use of devices”. It reveals to demonstrate Gaba’s thoughts on simulation advantages.

Simulation is a safe environment that encourages experimental learning which attempts to bridge the gap between “knowing” and “doing” (Flanagan et al., 2004) by providing opportunities for learners to practice newly learned skills. Thus, simulation was

found as a tremendous tool for healthcare educators. Healthcare professions and trainees are artificially placed in similar or new situations that can be replicated. It allows them to achieve learning goals without exposing real patients to risk.

C. History of Healthcare Simulation

Simulation in medicine started in the early 1960s, when "Laerdal", a Norwegian Company created "Resusci Anne", a tool to foster learning of cardiopulmonary resuscitation skills (Cooper and Taqueti, 2004). That model grew from the work of Dr. Peter Safar, who developed the first mannequin to teach the effectiveness of mouth to mouth ventilation and to improve resuscitative skills in 1958. Safar's publication urged a Norwegian toy manufacturer, Laerdal to create the training mannequin for mouth to mouth ventilation. Then, Laerdel created a spring mechanism in the chest to simulate chest compressions (Grenvik & Schaefer, 2004). These accomplishments are the initiators to use simulation in medicine in order to teach cardiopulmonary resuscitation and to alter the training environment in healthcare.

In the late 1960s, Dr. Stephan Abrahamson and Dr. Judson Denson developed a computer controlled patient simulator. The mannequin was known as "Sim One", with many high-fidelity features that were controlled by hybrid digital and analog computer (Cooper & Taqueti, 2004). Proficiency studies among anesthesiology trainees using "Sim One" showed a higher level of performance in the operating room than the trainees who did not use simulator training (Abrahamson et al., 1969).

CHAPTER II

BACKGROUND AND LITERATURE REVIEW

A. Medical Errors

1. Definition

In the Institute of Medicine (IOM) report "To Err Is Human", defines an error as "the failure of a planned action to be completed as intended (error of execution) or the use of a wrong plan to achieve a goal (error of planning)". In the first situation, the desired result may or may not be accomplished, and in the second situation, the desired result can't be accomplished. James Reason defines an error as "the failure of a planned sequence of mental or physical activities to achieve its intended outcome when these failures cannot be attributed to chance," or one that does not achieve its intended outcome (Leape, 2002). Medical error is a deviation from the process of care that may or may not cause harm to the patient. It might occur in all healthcare settings not only in hospitals but physician's offices, pharmacies, urgent care centers etc. (Agency for Healthcare Research and Quality, 2000)

2. Medical Error Rate

Based on the IOM report "To Err Is Human" (2000), studies were done in New York using 1984 data and Colorado and Utah using 1992 data, the proportion of "medical

errors resulting in injury" (preventable adverse events) attributable to errors 58% and 53% respectively. Preventable adverse events are one of the leading causes of death in the U.S.

These adverse events increased disability lasting for six months or less, 13.6 % resulted in death and 2.6% caused permanently disabling injuries. An adverse event can be a drug complication (19%), infections (14%), and technical complications (13%).

These two studies show that between 44,000 and 98,000 Americans among 33 million individuals hospitalized die in hospitals every year due to medical errors. In 1993 medication errors, another leading cause to death, accounted for about 7,000 deaths. High error rates likely happen in intensive care units, emergency department and operating room.

Although, other studies mention that the IOM report in 1999 underestimated the actual number of medical errors. A 2004 report of hospital deaths released by the Agency for Healthcare Quality and Research Patient Safety Indicators (HQRPSI) in the Medicare population shows that there is 575,000 death due to the medical error between 2000 and 2002, which is almost 195,000 deaths annually (Ramanathan et al., 2014).

Similarly, in 2008, the Office of the Inspector General in the US Department of Health and Human Services (US IG), reports 180,000 annual deaths caused by medical error only among the Medicare receivers. Classen *et al*. (2013) shows above 400, 000 deaths annually, which is four times higher than the IOM estimation. In addition, Landrigan and colleagues reported 63% death caused by medical errors among 10 hospitals in North Carolina between 2002 and 2007.

James claims that the actual number of deaths from medical errors may be in the hundreds of thousands (James, 2013). It is surprising to know the true number of medical errors because it is unreported (Bayazidi *et al*., 2012). Unfortunately, that is happening in our region. The reasons behind underreporting are, not considering an error as a medical error if it is not leading to harm or death, lack of people awareness (Lederman *et al*., 2013), fear of consequences, and lack of trust between management and staff (Almutary and Lewis, 2012) . Van Den Bos emphasizes that medical errors are not accurately estimated. It is essential to differentiate between medical injury and medical error. Medical injury is medical care with an adverse outcome due to unavoidable complications. While medical error is a preventable adverse outcome with a mistake in commission rather than a mistake in omission (Van Den Bos *et al*., 2011).

3. Causes of Medical Errors

The IOM report ensures the importance of healthcare system's role that is involved in errors. James Reason (1990) extended the analysis to test the role of systems and the human contribution to errors. "A system is a set of interdependent elements (equipment, technologies, etc.) interacting to achieve a common goal".

Human error is one of the contributors to accidents. As estimated by Charles Perrow (1984), 60 to 80% of accidents involve human error. Human error in anesthesia contributed 82% of preventable events and the remainder contributed equipment failure.

Providing a safe healthcare system is reached by considering the psychological limits of people and providing tools to reduce or eliminate the preconditions consequences. They are failures connected to the system and might occur without recognizing them. Such as the need to have the right equipment, reliable, experienced and knowledgeable people, effectively designed jobs, efficient work schedule, and clear monitoring of performance (IOM Report, 2000).

Besides, technology contributed to system complexity. Although technology reduces human efforts and decision making that reduce human errors. Nonetheless, technology might contribute to healthcare errors due to equipment breakdown or machine failure.

Emanuel (2008) states that miscommunication among healthcare professionals is one of the main causes. It is becoming clear that many providers do not work together to provide the best medical outcome for the patient. Similarly, Brownlee (2007) points out that the lack of cooperation among the players in the current health care delivery system is one of the major reasons for the epidemic of medical errors in medical care.

Annual death of Americans is a result of medical mistakes commonly caused by equipment failure, misdiagnosis, miscommunication, medication errors, and failure to rescue patients (Kohn, Corrigan, & Donaldson, 2000).

Studying human performance can result in a safer system and reduces the conditions that lead to errors. Studies in human factors improve the human–system

interface through designing effective systems and processes, and human-machine interaction by redesigning equipment (Leape, 2002)

Recently, hospitals face limited staffing, and less hospital stay. Thus, it is difficult to identify effective methods to decrease human error and increase patient safety. Hence, improving individual performance is not solely important but also focuses on system failures and improving team performance (Agency for Healthcare Research and Quality, 2006). As a result, the IOM report has suggested the use of simulation as a method to improve patient safety in healthcare organizations (Kohn *et al*., 2000).

B. Cost of Medical Error VS Cost of Simulation Investment

High error rates are positively correlated to the cost of healthcare delivery, requiring longer hospital stays, causing disability, death and the trust issues in medical care.

Health care costs account for over half the total national costs. They were estimated to be between $37.6 billion and $50 billion, while preventable adverse events were between $17 billion and $29 billion.

Medication errors costs are higher in hospitals. Studies done in teaching hospitals found that about 2% of inpatient experienced an adverse drug event. It accounts for $4,700 per admission. They stated that the preventable adverse drug events leading to increased hospital costs for almost $2 billion nationally (IOM Report, 2000). The IOM (1999) conducted that drug errors alone add $5,000 to the cost of every hospital admission.

A study by Jill Van Den Bos and colleagues in 2008 estimated the total cost of measurable medical errors in the United States was $17.1 billion. The Canadian Institute for Health Information's (CIHI) reported in 2004 the extra added cost of health care that might be attributable to medical errors was $750 million.

In comparison, integrating simulation in the healthcare field for learning and evaluation purposes require many considerations. Bond and Spillane (2002) mentioned that investing in a high-fidelity simulator costs $200,000. Nehring and colleagues (2002) mention the faculty considerations to run a successful human patient simulator, (a) time, effort, and commitment to learning software and hardware of the simulator, (b) assigning a faculty member for troubleshooting the technology and set up the laboratory, (c) train faculty members on the capabilities of the simulators' technology to avoid equipment malfunction, (d) time to plan, design, and test simulation scenarios independently, (e) knowledge, experience, and evaluation criteria are required by the faculty. Besides, the administrative considerations, other than the initial cost of simulators, administrators must consider the maintenance expenses and the need to upgrade the software or equipment. In addition, money and faculty time needed for training and practice (Nehring *et al*., 2008). Gaba mentions that time must be dedicated for training and practicing aside from clinical work, that will require significant additional costs (Gaba, 2004). In addition, evaluations time to measure students' attitude of using the human patient simulator (Nehring *et al*., 2008).

Motola and colleagues correctly argue that acceptance and support from the administration and the faculty to commit the needed resources come first. To align the

available resources with the scope of the simulation program whether it is on a small or large scale (Motola *et al*., 2013). The initial investment of faculty time is needed to evaluate the program and determine the best practice to integrate simulation in learning. In addition to the time and scheduling challenges, other challenges must be considered. Balancing between the patient care duties during clinical service and practicing the simulation components (Issenberg et al., 1999). Faculty support in developing simulation scenarios, providing technical assistance, and programming cases are essential in achieving successful and effective implementation of the program. Moreover, ensure satisfaction and development of the learners and instructors to ensure effective educational outcome (Thompson & Bonnel 2008).

Time, human and technology resources are major investments in simulation laboratories to improve learning and reduce costly medical errors. But the ability to practice without threatening risk must be compared to the cost of the new technology. A high-fidelity simulator with its necessary equipment may cost up to $200,000 (Bond and Spillane, 2002). Kurrek *et al*. (1997) estimated the construction cost of a simulation facility to be $665,000. Tuoriniemi (2008) states that investing on simulation might vary between $200,000 and $1.6 Million Dollars. Gaba suggests that the expenses of implementing medical simulation depend on the target population, the aim of simulation, technology needed, the ability of the educational and clinical organization to succeed in restructuring its work to integrate simulation-based learning, as well (Gaba, 2004).

C. Reasons of Adopting Simulation in Healthcare

Healthcare simulation is a vigorous educational tool that facilitates learning for practitioners to improve patient outcomes and safety (Zigmont *et al*., 2011). The integration of simulation becomes completely an educational and assessment technique. Studies conducted that simulation-based education and assessment improve individual, team, and healthcare industry performance. However, it took several decades to prove that, but evidence proves that simulation improves patient care, decreases injury, and decreases mortality. The Institute of Medicine (IOM report) claims that simulation has led to a reduction in medical errors. The report shows 60–90% of preventable deaths from medical errors have been avoided through utilizing simulation in medical learning and the major threats to patients are now systems-based deficiencies (Levine et al., 2014, p. 651).

During the past two decades, the use of simulation in health care has grown rapidly for the purpose of improving patient safety (Gaba, 2004). Although the resistance to adopting simulation by practitioners and in the healthcare field. Acceptance, visibility and focused role of simulation have started to dominate (Levine et al., 2013). Okuda suggests that simulation provides the perfect opportunity to exercise patient care off from the bedside and to apply the concept of "deliberate practice" and "adult learning" to promote effective acquisition and retention of clinical skills (Okuda et al., 2009).

Adult learning theory serves as the foundation for simulation-based training. It is well known that adults learn by different methods because they are more independent and self-directed (Wang, 2011)

The utilization of simulation technology for teaching and learning in medical education significantly increased. Scalese and colleagues (2007) imply that the worldwide focus on medical error problem and the importance to improve patient safety, changes in healthcare delivery and the limited availability of patients as an educational opportunity; changes the outcome-based education and its requirement for competency assessment.

Analogously, Issenberg and colleagues argue that healthcare simulation has been adopted for education purposes. The driving forces for this adoption, other than technology development, change in healthcare delivery (higher illness and shorter hospital stay decreased the practice opportunity at academic medical centers) and for residents, it's hard to balance between their daily tasks with time for education and assessment (Issenberg *et al*., 1999).

Other professions as aviation and military had successfully integrated simulation technology to train and assess pilots and military personnel. But, these simulation-based programs focus on the effective collaboration in teams and a safe-oriented culture, and not only on developing and evaluating individual skills (Scalese *et al*., 2007). Medical education adopted these models, known as Crew Resource Management (CRM). Gaba and colleagues realized the importance of integrating the CRM program to simulation-based education. To teach the concepts of team behavior and assess decision making, develop team management and interpersonal communication. Crew resource management training program introduced effective communication in teams to help a positive change in practice (retrieved from Bhagwat, 2012).

The shift to simulation-based education decreased the traditional practice of "see one, do one, teach one" approach and it is considered non-ethical to use real patient or even standardized patient for training purposes (Ziv *et al*., 2003), because of patient safety and fewer patients availability. Similarly, Rehrig *et al*. (2008) endorse the traditional apprenticeship model of learning is becoming abundant.

Beyond the use of simulation for training and teaching purposes, simulation has been used for competency assessment (Murray, 2004). According to Kochevar, "while student learning is clearly the goal of education, there is a pressing need to provide evidence that learning actually occurs" (Kochevar, 2004). The simulation scope shifts to focus on outcome-based education throughout healthcare professions, and it is an appropriate model for considering the best practice of simulation technology for testing purposes (Scalese et al., 2007). The Accreditation Council for Graduate Medical Education in the US (2006) describes 6 fields of clinical competence: (1) patient care, (2) medical knowledge, (3) practice-based learning and improvement, (4) communication and interpersonal skills, (5) professionalism, and (6) systems-based practice.

Therefore, simulations are the most suitable tool to evaluate those outcomes (ACGME, 2006). However, few studies showed a positive direct influence of utilizing simulation for medical training in the clinical outcome (Okuda et al., 2009).

D. Simulation Facilities and Simulators

Simulation-based medical education can be either conducted in an off-site simulation setting in simulation centers or in situ simulation. Simulation centers found in universities and hospitals building, and some off-site simulation is in-house training rooms within the hospital departments, but away from clinical setting and only for simulation training. On the other hand, in-situ simulation occurs in the actual patient care units (e.g. emergency department and clinics) where the actual team is involved in their own working environment (Riley *et al*., 2010). Rosen and colleagues describe in-situ simulation as a mix of simulation and real working environments to provide training for practitioners in an actual workplace (Rosen *et al*., 2012).

Each simulation facility can accommodate specific or preferable simulator types. A Simulator is defined as "a physical object of the full or part-task to be replicated" (Cooper & Taqueti, 2004). There is no universal classification of simulators despite their significant development and sophistication. Simulators are classified into three categories, according to their correspondence to reality known as "fidelity" (Seropi *et al*., 2005). While, Cumin and Mary (2007) proposed a simulator classification according to "user interaction", "physiological base" and "utility bases". The categories of simulator have developed from part task trainer to complex computer-based system. While Cooper and Taqueti (2004) structured simulators into five categories according to David Gaba's scheme. These categories are "verbal", "standardized patients", "part-task trainers", "computer patient" and "electronic patient". Verbal simulation is a role-playing, as safety conferences to distribute information about the simulation that began in 1988 through 1989.

Because mannequin was exhibited long before it was commercialized (Cooper & Taqueti, 2004). The use of Standardized patients began in 1963 with neurologists from the University of Southern California to teach third-year medical students. SPs are actors used to teach and assess the expertise, diagnostic skills, and communication. They are usually utilized in a simulation center or in-house simulation (classroom). However, this method was not accepted because it was expensive and unscientific (Barrows & Abrahamson, 1968). Part task trainers are body parts in a normal state or symbolizing disease. They are low-fidelity simulators (lack the realism), usually used to teach technical skills as "Resusci Anne". That was designed as the death mask of the "Girl from the River Seine", a French drowning girl. Part task trainers were not only used in the surgical domain but also for cardiology skills, as the Simulator-K partial mannequin (Takashina *et al*., 1990) and the Ultrasim in 1995, it is an ultrasound mannequin that was the first to include instruction manuals and clinical presentations (Rosen, 2008).

The Internet-based virtual world functions as the standard patients (Rosen, 2008). "Sleeper" the current BodySim software was developed by N Ty Smith and colleagues who have experience in anesthesia and cardiovascular physiology (Smith and Fukui, 1981). In the 1990s new software was added known as Anesthesia Simulator consultant to become as the Anesthesia Simulator after improvements (Cooper & Taqueti, 2004). In the 1990s Gas Man software was created, it presented a computer-based tutorial on anesthetic gas distribution (Philip JH, 1986). Laerdal designed a multimedia product known as "MicroSim" to practice resuscitation and medical emergencies (Perkins et al., 2006). Anesoft cardiovascular products appeared also in the 1990s: first, the Critical Care

Simulator in 1995, second, the Hemodynamics Simulator in 1998. The Web-based programs to experience and learn medical skills were first introduced in the 1990s (Bergin and Fors, 2003).

Electronic patients can be either a mannequin or virtual reality- based. Rosen claims that the mannequin simulator in anesthesia was first described in the late 1960's before the human or technology was prepared for it. The first full-scale human patient anesthesia simulator was built at the University of Southern California. SIM 1 had blinking eyes, pupils with changing size, and opening jaw. The mannequin had a respiratory motion and synchronized heartbeat with carotid and temporal pulses and connected with blood pressure (Rosen, 2008). Mannequins are usually used in simulation center and in-situ simulation. Moreover, SIM 1 responded to drugs and airway management (Cooper & Taqueti, 2004; Good, 2003). The first full-scale mannequin was launched in 1988 after he partnered with CAE-Link. The mannequin was constructed using the CASE system, the Anesthesia Simulator Recorder mathematical model and the CAE-Link technology (Gaba, 1988).

The development and acceptance of human patient simulators were slow but accelerated into these days. By the end of the 1990s, mannequins, and CRM have started to overrun many medical disciplines other than Anesthesiology, like pediatrics, Emergency Medicine, Trauma, Cardiology, Intensive Care Medicine, and Dentistry (Watterson *et al*., 2000). High- fidelity mannequins started to appear in the 2000's, such as SimMan and SIMA a computerized infant mannequin in 2005 (Halamek *et al*., 2000).

Medical VR- based simulators started to appear in the mid of 2007 at the Ann Myers Medical Center. Virtual reality haptic (touch) simulator immerse the learner in a dynamic, realistic, complex setting using a computer-assisted design that offers a tangible feeling of reality and immediate feedback, for example, completing a bronchoscopy procedure (Issenberg *et al*., 2005). This simulator type is most used at simulation centers and within medical surgery centers for training.

E. Comparison between Simulation Center and in-Situ

Simulation center and in-situ settings both enhance the individual and team learning outcomes (Sorensen *et al*., 2017). But Patterson *et al.* (2013) claims that the in-situ in the emergency department (ED) showed effective strategy to implement teamwork training and identification of potential threats are higher than in simulation center. On the contrary, Patterson and colleagues (2013) shows that simulation center provides a good practice of crew resource management principles, ability to realize potential risks to patient safety, and improved safety procedures in their institutions. In situ simulation is more realistic, 59% versus 10%, and more effective 45% versus 15% than simulation center for teamwork learning (Couto *el al*., 2015).

1. Advantages and Disadvantages of in-Situ Simulation

Sorensen *et al* (2017) compares the advantages and disadvantages of the various simulation settings related to simulation-based medical education components. In-situ

simulation is preferable for practitioners because it resembles reality more than off-site simulation and this would affect their involvement ability (Sorensen *et al*., 2015). According to Patterson *et al* (2013) in-situ simulation is more effective than simulation centers because it is performed in a highly authentic place. In-Situ simulation and off-site simulation setting is useful to identify organizational deficiencies (Sorensen *et al*., 2015). However, Sorensen *et al* imply that there are few studies that show the impact of the two settings on individual and team learning. Moreover, simulation is used to test equipment, new procedures and physical environment. Then, in-situ simulation setting is considered more effective in providing information on technology and tools deficiencies (Carayon *et al*., 2007). Besides, other studies showed that in-situ simulation can be established with lower cost by utilizing local facilities and equipment (Rosen *et al*., 2012, Calhoun *et al*., 2011). Similarly, Lois *et al* conduct an observational study on the cost and feasibility between the two settings and it shows that in-situ account for 235 Euro/person while 500 Euro/person in center. However, Palaganas (2014) mentions that in-situ simulation requires storage space for equipment and scheduled time to manage human patient simulators. Hence, simulation educational planners must be ready to postpone or cancel an In-situ simulation session due to high volume or shortage of staff (Bullough *et al*., 2016). Besides, In-situ simulation can compromise patient safety (Palaganas, 2014) due to the mix up with real medication (cross-contamination), or medical equipment and utensils used for simulation that might not be safe and ready to use in real clinical cases (Moller *et al*.,2012).

2. Advantages and Disadvantages of Simulation Center

Off-site simulation in simulation center provides safer learning environment (Savoldelli *et al*., 2005) and potential conflicts of interest between simulation instructors and healthcare professions can be avoided. Besides, longer duration is dedicated to simulation session, especially for debriefing (Moller *et al*., 2012). Konge *et al*. (2016) correctly argue that simulation center has better facilities to emphasize efficient utility of high-tech simulation equipment. Simulation center provides easier access for technicians in case of equipment malfunction or technical issue (Sorensen *et al*., 2015). On the other hand, Sorensen *et al.* (2017) believe that simulation center provides less involvement of all healthcare professions; fear of calling away practitioners from their clinical work, lower accessibility of staff due to required travel time from clinics or hospital to the center, as well. Other drawbacks don't seem crucial to invest in a simulation center. Hence, the comparative study by Couto *et al*. (2015) about evaluating team skills in both settings show similar scores. Although, investing in a simulation center is quite expensive comparing to in-situ setting.

designing a simulation center, how the process evolved and what is the decision-making approach.

F. Basic Design Considerations for a Simulation Center

Seropian and Lavey (2010) suggest design considerations for simulation facilities. Yet there is no optimal or best practice in simulation center design, due to several factors as

mission and vision, budget, space and functional need that contribute to the design of simulation facilities. Seropian and Lavey (2010) specified two simulation room layouts. First is the open learning room, which accommodates 25 to 50 people with mannequins and beds. Second is the simulation theatre, which represents a specific simulation environment. In a further study, Seropian *et al*. (2015) focus on a high-fidelity simulation room, which focuses on the size rather than the function. The basic components of a simulation center are: (a) simulation room where the simulation scenario is happening and its flexibly designed to accurately portray realities of the healthcare situations, (b) control room is a high-tech room with a unique environment which allows the instructors observe and assess practitioners, and control the mannequin (e.g. adjust the light or regulate sound to act the medical situation). Use a combination of one-way mirror and audiovisual equipment is a multilateral option for a better visionary. Nelson (2013) thinks that elevating the control room from the floor for a better view to the simulation room and the underneath space can be used for storage; (c) debriefing/conference room is a meeting room that accommodates pre-briefing and debriefing, typically with a center table and chairs, and a monitor for presentation or video recorder. Instructors distribute materials and contents about the simulation session. An important consideration is not to have debriefing rooms less than simulation rooms to avoid conflict. Kutzin *et al*. (2016) recommend using dry erase paint on all the wall surfaces to use all the available wall spaces and it provides a long review of the previously reviewed content, (d) multipurpose room is a fully equipped room that can be transformed to meet the learner's need, flexible to act as an emergency room, medical intensive care unit or operating room, (e) standardized patient environment, (f) medication room it is not a requirement but it adds reality and fidelity to the center, (g) storage room is

an important area for storing equipment, consumables and mannequins. Studies show that 10% to 25% of the overall center area should be specialized for storage. Besides, more flexible rooms with fewer shelves fixed help more storing, (h) preparation room is used by faculty or instructors to prepare the simulation scenario. It requires a sink and counter space for preparing biological materials, (i) offices for operational personnel. It is preferable to locate the offices close to the daily activities. Moreover, a reception area for administration, (j) restrooms and other specialty areas (e.g. server room that requires specific electrical and ventilation considerations and should be air- conditioned because of the generated heat by the equipment). Seropian focuses on space flexibility to accommodate and mix different objectives, and identify the maximum capacity that the facility can accommodate

Other aspects to consider in the design are the door size and hallways width for easy equipment access. A hospital bed requires about 1.07 to 1.22m to pass through a door or hallway. Carpeting should be used for debriefing rooms and offices. Controlling the sound level in a simulation center is a complicated issue because of several sound sources (e.g. equipment, ventilation system, electronic systems, and sound from adjacent rooms and passages). Wall sound-absorber, acoustic ceiling tiles, and full height walls can reduce sound level (Seropian and Lavey, 2010).

Similarly, Kutzin conducted a study based on experience about simulation design considerations that can increase utilization and optimize expenditures. Both studies provide the considerations of a simulation center, e.g. what room functions they need to consider and for what purposes. But few or no studies were conducted about the decision criteria the

stakeholders should follow in order to optimize their given space, budget, and resources to meet their program's needs and goals.

A Healthcare simulation center is considered as learning and testing tool. Simulation is utilized in hospitals or in educational institutions in order to train and teach both individual and team skills. As well as, simulation is a testing method for healthcare system's efficiency and performance. Thus, planning and designing a simulation center is treated similarly to designing any healthcare facility along with educational facility.

Long time ago, the importance of layout and design of the physical workplace was recognized in shaping organizational behavior. The space and layout attach the function and the social aspect of a building. Hence the relationship between people is reflected in the structure of the space within this construction (Kallio *et al., 2015*). Similarly, Stryker *et al*. (2012) show that communication at workplace is influenced by specific physical design characteristics of the working environment.

Building a healthcare working environment plays an important role in various factors; staff satisfaction (Tumulty, 1994), patient safety and experience, and operational efficiency (Reiling, 2007). But, from decades ago, designing healthcare facilities have not been aligned with developed clinical roles (Lamb *et al.,* 2010). A study shows that the physical working environment is a major contributor to nursing turnover (Scott, 2006). Inefficient layout, patient access, lighting conditions, and acoustic environments may contribute to workers' stress levels (Chaudhury *et al*., 2009). Thus, we are not surprised by healthcare system deficiency and poor nursing performance because of obsolete nursing

processes. As a result, the architectural design phase is crucial to determine which processes to enhance (Scott, 2006).

Moreover, there are consensus towards learning environments and laboratories. Taylor highlights that architects should know who and how the learning spaces will be utilized (Taylor, 2009). Mahony *et al*. (2011) in particular, suggest new social architecture, which seeks evaluating and assessing the relationship between space and learning. Educational facilities' features affect learning outcomes (Higgins *et al*., 2005). However, the factors and impact variables are not clearly linked (Mahony *et al*. 2011).

Heitor *et al*. (2009) discuss one of those impact variables, space flexibility in a center or laboratory allows all classes types to be given, regardless of discipline (Arzi, 1998). However, Dovey and Fisher argue two types of flexibility, the 'convertibility' of plans from one-pedagogy to another and back, and the 'fluidity' for continuous learning between activities. Both healthcare facilities and learning spaces should reinforce 'flexible', 'adaptable', 'sustainable', 'inclusive', 'safe', 'comfortable', 'scientific', 'natural' and 'technological' settings (Dovey and Fisher, 2014).

Implementing successful healthcare models is dependent on the physical conditions of the healthcare facility (Henriksen *et al*., 2007). Thus, the architectural work is crucial to bridge this gap, making bad decisions in healthcare architectural building can negatively impact people and work processes for a long time (Becker and Parson, 2007). Important decisions are made by stakeholders in the early stages of the planning and designing phase. In this phase stakeholders discuss ideas and project requirements

(Pemsel *et al*., 2010). The main aim of this phase is to determine the healthcare environment from the end users' perspective and integrate it to the organization's strategic plan (Barrett and Baldery, 2003).

Planning for a healthcare environment requires deep analysis of people's needs and objectives that the healthcare is expected to meet and integrate to the workspace conditions and care processes (Steinke *et al*., 2010). The involvement of direct caregivers is crucial during the early design phases of any healthcare construction.

Before focusing on the details of simulators while designing a simulation center, one first needs to plan for the physical space environment in which training will take place. The process of starting up a simulation facility initiates with specifying needs (1) "the scope of the educational mission and learner group" (2) defining the relation between any department and institutional needs (Smith, 2010). Miller *et al*. (2016) imply that the architectural human simulation aims to present the workflow in the design of the sophisticated cooperative workplace. A study by Murphy (2013) on utilizing "Plan Do Study Act" to transform the current simulation setting to a simulation center shows that updating the physical environment have positively influenced student learning, increased students' satisfaction through increasing environmental fidelity, creating a functional 'user-friendly simulation center'.

Thus, achieving an efficient workplace for an effective testing tool and an effective learning environment. Simulation center is build based on realistic features of healthcare spaces, real functionality, space, workflow and layout. A gap

exists in literature about the process of designing and implementing simulation-based hospital and its challenges.

Penn Medicine clinical simulation center are sharing their experience in building the new simulation center of 2,044 m2, Williams *et al*. (2010) acknowledge the features of a simulation center, but not the approach of designing this center. Similarly, Eagle *et al*. (2010) describe the Mayo clinic simulation center, a 930 m2 space which accommodated 6000 practitioners in 2008 through intensive schedule. Accommodating such a large number in the given space is achieved through effective scheduling of resources, equipment and space.

Lazzara *et al*. (2014) argue eight factors in creating and implementing effective simulation program, science, staff, supplies, space, support, systems, success, and sustainability. The 8S factors of a whole integrated system of personnel, equipment, and space. Davies A, Davies J. (2015) highlight that there is a data shortage in utilizing simulation to test hospital's system. But system testing can't be efficient if the system is not designed. Therefore, simulation center's system should be well planned and designed for such purposes and for an efficient workspace.

In this research, we suggest and describe strategy to reinforce shared-decision making when planning and designing new healthcare simulation facility. The approach utilized help creating and developing design guidelines for an optimal healthcare simulation center.

G. Rationale of the study

The purpose of designing a simulation center instead of having in-situ simulation is the lack of clinical space availability, low accommodation in clinical areas, and faculty member shortage (Jeffries, 2005). However, designing and implementing simulation center takes extensive time, planning, and follow up by authentic people (Rothgeb, 2008). Building a simulation center is complex, planning and designing the center requires team members of healthcare specialists, owners, architects, IT and audiovisual consultant, simulation design consultants and engineers. Besides, simulation centers can be extremely expensive. Including manikins' cost, construction cost, available equipment and tools needed to mimic real life and resemble reality, faculty training, IT and staff needed to manage and run the center. Additional costs can include purchase of scenarios, maintenance for manikin, computers, audiovisual equipment, furnishing, and medical supplies (Jeffries, 2005; Rauen, 2004). Therefore, great planning and optimal designing for a simulation center is needed. In order to meet organizational needs and goals along with optimizing costs and time. However, the approach for an efficient and optimal design is not really covered in literature. Mere literature by scholars and researchers on the process of designing a simulation center, how the process evolved and what is the decision-making approach.

H. Research Question

After reviewing the literature review and facing struggles in finding design considerations in designing the new medical simulation facility at AUBMC we seek answers for our big research question:

- What are the guidelines and key considerations to develop and design a medical simulation center-based program?
  - What are the challenges of designing a healthcare simulation center?
  - What is the decision-making approach to plan and design a simulation facility?

CHAPTER III

METHODOLOGY

A. Design

This study is a cross-sectional exploratory case study, it provides the ability to go beyond the quantitative statistical results and observe the behavioral conditions through the users' perspective. It is a case study targeting medical simulation experience in Lebanon and specifically the AUBMC experience and the study design helps describe both the process and outcome of this matter through observation and analysis of the case. For that reason, we have decided to undertake multidimensional, quantitative and qualitative, data analysis.

This exploratory case study tends to target a new problem that has a limited research data to date. And it helps us have a better understanding of the intended subject, without previous thoughts and expectations. It will help us apply different methodologies and rely on various sources to investigate our research question. This research is rare and this methodology design will provide a detailed description of this specific case at the American University of Beirut Medical Center (AUBMC). We have decided to use this research design in order to explore our objectives and aims based on the literature, leaving room for potential future research.

B. Setting

Our research took place at the American University of Beirut Medical Center and simulation facilities in Beirut-Lebanon.

C. Participants and Recruitment

We will conduct eight semi-structured interviews with personnel experienced in medical simulation and with stakeholders involved in the design process of the AUBMC simulation center over a four months period, starting late August and ending late December; 2018. Respondents a cross-section of industry sectors including: three simulation facility coordinators, one simulation facility director, one architect, one information technology (IT) or Biomedical Engineer (BME), and two project consultants.

Our study is approved by the International Review Board (IRB). Participants will be recruited through an e-mail sent by the co-investigator. We specified our participants through snowballing sampling technique, where other interviewee recommends other participant, whom they have experience in medical simulation. For snowballing, the investigator can give the contact details of the research team to the potential participants who can pass them to others who may be interested in taking part in the study (e-mail invitation can be forwarded by participants in the field). Those interested can then contact the research team or the research team may contact them if they gave approval to be contacted. Besides, we aimed specifically to interview stakeholders involved in this project at AUBMC. Participants will be asked for meeting at their convenience in their premises,

convenient day and time, and it will take place at the simulation facility or participant's office.

Through a formal consent form (APPENDIX II), that will be read and signed by the participant, we ensure participant's anonymity and confidentiality. The interview will be recorded if the interviewee approves, notes and comments are written, as well. The interview estimated time will be between 30 to 60 minutes.

We developed the interview guide based on a review of the current literature related to this field and based on observations. We tested the interview guide with the first participant, and we decided to amend it. Afterwards, we developed and edited the last draft with authorized simulation personnel in "Qatar Sidra Simulation Center". The questions for the interview were framed around the functions and operations of the simulation facility, the equipment and resources, education and program offerings, and challenges and recommendations. There are open-ended questions that help the interviewer gain more knowledge through follow up questions and closed-ended questions. The interviewer will ask non-scripted questions to either clarify or expand on a specific point mentioned by the interviewee.

Interviewees will be aware that their participation is voluntary and could discontinue participation if the felt the need to. Interviewees will be aware of that through a consent form that would be signed before the start of the interview. The aim is to conduct around 8 interviews.

D. Data Analysis and Disposition of Results

We approach our analysis through qualitative analysis and quantitative analysis. The study utilizes **triangulation analysis** from different sources of data to reach our findings. That is beneficial to gain more understanding from different perspectives and to increase the level of knowledge to strengthen our study from various aspects. Triangulation contains first, **perceptions** (semi- structured interviews and changing the questions of the interview based on the interviewee interest and industry sector) (APPENDIX III), second, **validation** (direct observations in simulation facilities, in-situ simulation sessions, and design meetings at AUBMC conducted by the investigator, shown in Table 1) in order to understand and immerse in the simulation experience, third, **documentation** (document review for the 2D-drawing of the new medical simulation facility at AUBMC). Potentially, with the gathered data we reach our study findings validating them with peers and experts of the industry. This validation will ensure credibility and authenticity of our methods and conclusion.

Location	Date	Attendees
AUBMC Design Meeting	Oct-6-2017	Design Stakeholders: Director of sim center Chief planning and transition officer Architect Consultant IT
AUBMC Design Meeting	Oct-12-2017	Director of sim center Chief planning and transition officer Architect Consultant IT Simulation Coordinator

In-situ simulation (Emergency Department)	Nov-16-2017	2 Doctors Group of 4 practitioners (residents, physicians) Simulation coordinator 1 BME
In-situ simulation (Emergency Department)	Nov-30-2017 Dec-21-2017 Dec-28-2017 Jan-28-2018	1 Doctor group of 5 practitioners simulation coordinator

Table 1 Direct Observations Conducted by Co-investigator

For the qualitative data analysis, **thematic analysis** was manually conducted to identify themes or specific patterns for a chunk of data said by the interviewee. We are following four steps for thematic analysis, step 1 is data entry, where data is transcribed and the investigator gets familiar with data, step 2 is generating initial codes, where data is organized and reduced to smaller chunks in a systematic and meaningful way, two analysts generated initial codes to achieve a common sense from two perspectives, step 3 is searching and creating categories and subcategories that has to say something about our research question, step 4 defining themes, connecting related categories and defining them under essence themes that is categorized by its significance.

This study is supported with **quantitative data analysis** using the Statistical Package for Social Sciences (SPSS). Some collected data are quantitative and other categorical data are quantified to export it into SPSS as nominal and ordinal variables. Preliminary descriptive analysis (averages and standard deviations) is conducted for continuous variables, and frequency analysis for categorical variables.

E. Confidentiality

The data collected from interviews will be stored on a password secured laptop. The data will only be accessed by the principal Investigator as well as the co-investigator. Data will be kept for 10 years and then destroyed.

CHAPTER IV

RESULTS

A. Thematic Analysis

In the initial data familiarization phase, we found complex and different concepts to enrich our findings from data provided by the interviewee, other than short straightforward quantities and keywords that are quantified as categories into SPSS.

In the early stage of the analysis, all interviews were transcribed and 2 analysists (co-investigator and research fellow) generated initial codes from two perspectives, then we found a common sense between both to generate common codes. For detailed description of codes, see. Then, the first level codes were grouped under different categories and subcategories. We found that some categories are related to each other. Therefore, we grouped some categories under broader themes (fourth level) based on a shared concept or meaning. 8 major themes were generated in this study, **administration** with 3 categories (accreditation, program offerings, and staff training program)**, light** with 2 categories (natural light and artificial) **, organization of space** with 8 categories (location of rooms and flow around, function of rooms**,** observation room and capacity, storage room and capacity, debriefing room and capacity, isolated/controlled rooms, private areas, reception and waiting areas) and 2 sub categories (OSCEs and flow, simultaneous sessions) under the category 'function of rooms', **equipment** with (system brand, audiovisual capacity, simulators, preventive maintenance program, furniture)**, design or current challenges,**

changes and constraints in design, ideality and optimality, recommendations and expectations (as shown in Table 2)

Initial codes were generated from concept repeated by more than one participant. For example, design considerations for accreditation was repeated by 2 participants (n=2), multidisciplinary simulation (n=6), industry training (n=3), multipurpose rooms (n=8) etc. but some codes were generated from only one participant, specialist in the industry, because his/her quotation is important for the study and has to say something about the research question. Some examples of quotations (as shown in **Error! Reference source n ot found.**) to illustrate the coding process (not all quotations were included).

Main Theme (Fourth level)	Category (Third Level)	Sub-Category (Second Level)	Codes (First Level)	Quotation Examples
(1) *Administration/ Management*	Accreditation		Operational Experience(n=1) Financial Support(n=1) Design considerations for accreditation(n=2) International accreditation(n=2)	"The lab is not accredited because you need to have operational experience, Money is not the issue"
	Program Offerings		Multi-Disciplinary simulation(n=6)	"undergraduate program to the medical students, post-graduate programs for residents, fellows, career development for attendants and staff, and we are hoping to develop courses included in the curriculum, the nursing school they already have some courses so we can collaborate with them to introduce in our center, and also will also introduce medical simulation curriculum in the medical school"
	Staff Training Program		Industry Training(n=3) Seminars(n=2) Software and Hardware Familiarization (n=2) Hands on and online (n=2) Simulation education(n=1) Certification(n=1) Staff preparedness (n= 1)	"CAE would be training the staff on the use of the AV software; there are 4 types of training: to train for 3-4 full days on the software for 10 participants, secondly, Training for life--long-term contract with the CAE (web-based training as recorded trainings). Custom made training: Training sessions in Germany or the US free training. Webinars are offered".
(2) *Light*	Natural		Direct façade natural light in tutorial room(n=6) Functionality and natural light(n=3) Aesthetic design and place(n=3) Reflection(n=3) Reputation(n=2) Attractiveness (n=2)	"It is a peripheral natural light, the rooms inside do not benefit directly from the natural light they are not at the facade of the building"
	Artificial		Room functionality(n=1) Direct light in offices(n=1)	"unfortunately, no natural, but usually we don't need that in the hospital and especially in the NICU, in our offices we have natural light"

(3) *Organization of Space*	Location of rooms and flow around		Adjacent/ proximity(n=1) Functionality (n=1) Minimal intersections(n=2) Low redundancy(n=1) Spatial design(n=3) Architectural blueprint(n=2) Peripheral circular flow with star-shaped(n=3) Reality design(n=1) Lean flow(n=2) Multi-configurational (n=5) Design considerations (n=5) Optimized space and cost(n=2) Peripheral rooms(n=1) Central sequential flow(n=5) Design evolution Stations (n=1) Sequential linear flow(n=1) Back seen area and public area(n=1) star shape inpatient area(n=1) Flexible and functional corridors(n=3) Central function(n=5) Sequential functionality (n=4) Circular flow(n=4)	"Its shape is sequential with minimal intersections, not really so circular flow, the architectural plan looks like peripheral circle with a central functions and functions on the side. Combination of a circle with a star. It is not a redundant flow, back or forth flow" "the flow will be circular and that's how it was designed, it was designed in a way that you can move from one simulation to the next, so a patient can come in into a patient room to the OR then go to the recovery room then go to the ICU"
	Functions of Rooms		Multipurpose aka generic rooms(n=8)	"The function of the rooms is multipurpose they can do lectures, skills training and scenarios high fidelity" "Then they had to combine some rooms such as the LDR/Newborn care and NICU and for the Recovery/ICU-- so they worked on having more multifunctional larger rooms. Multipurpose room also next to the storage can be used for task training (for task training if they want to reduce noise outside because a special area for part-task training is in front of the simulation rooms), or most likely VR"

		OSCEs and Flow	Formative assessment(n=4) Acceptable flow(n=1) Efficiency(n=1) OSCEs(n=4) Corridors (n=2) Accessibility (n=2) Wall separation(n=1) International requirement (n=1)	"They do OSCEs in the lab especially for nursing. It is not currently being used for medicine because it is more efficient in the OPD “the flow is better with two corridors, rooms are separated. The setup for applying OSCEs is acceptable"
		Simultaneous scenarios	Functionality (n=8) Flow (n=50 Technical Feasibility(n=1)	"we run multiple scenarios, all rooms function together, and it goes well, the flow is great"
	Observation room and capacity		Central(n=5) In-room observation(n=2) Room specialty and independency (n=2) Purpose for location(n=8)	"1 control room that can be divided into two. This observation room with two-sided observer decks can observe the 2 sim rooms (pediatrics and neonatal) and we have big observation room far away from the sim rooms with no observational decks"
	Storage room and capacity		Accessible storage (n=7) Sufficient (n=7) Flexible (n=7)	"we have a big storage room with a sink, it is probably a size of one simulation room. We could have moveable shelves and it should fit one stretcher with a manikin in case it is not used with the scenario and we don't want to keep it outside and the other rooms are occupied, and closets"
	Debriefing room and capacity		In-room debriefing(n=2) Flexibility(n=3) High accommodation(n=5) Close to sim rooms(n=1)	
	Isolated/controlled room		‘server room’(n=6) External functions(n=7)	
	Private areas/offices		Privacy(n=5) Reachable offices(n=3) Friendly working area(n=5) Multi-functionality(n=2)	
	Reception & waiting area		Administrative purposes(n=8) Marketing purposes(n=5) Comfortability(n=6) Functionality (n=2)	
(4) *Equipment*	System brand		Live streaming(n=6) flexibility (n=1)	"CAE AV system because it functions with all other manikins’ brands"

	Audiovisual Capacity		Location Functionality Durability	"Each clinic have 2 cameras fixed to the ceiling, 1 speaker, and 1 microphone. The lounge contain speaker. Big sim rooms have 3 cameras, but the inpatient room doesn't have enough cameras yet in each cabinet. We have LCDs in all rooms and 11 mobiled that we can use it anywhere. mobiled camera we usually use it if we have scenario happening outside the center. we have 16 laptops for instructors and students, and we requested 8 more laptops. students and instructors use the center's laptops"
	Simulators		Program needs	"minimum 4 HF, 8 Mid-F, 3 LF and many part-task trainers"
	Preventive maintenance needs		Consultants support(n=2) Weekly Monthly Yearly	"What the company offers for the yearly maintenance and for major problems we call the technicians"
	furniture		Flexible Furniture(n=8)	"Debriefing rooms contain rectangular tables and moveable chairs. Not a classroom setting, but a seminar setting"
(5) *Design/current challenges*			Structure(n=1) Space constraints(n=5) human resource(n=2) project time(n=2) Budget(n=1) connections b/w contractors and consultant(n=1) handling stakeholders' opinions(n=1) layout organization(n=1) program challenges(n=1) list of requirements for equipment and tools (resources)(n=1)	"Shortage in staffing personnel like simulation expert other than a lab manager. Space and environment are kind of flexible, he can change the setup when needed"

(6) *Changes and constraints in design*			Flow(n=1) Sufficient storage(n=1) Shared control room(n=1) No changes(n=4) Space constraints(n=3) larger space(n=1) peripheral control room(n=1) improved audiovisual capacity(n=2) separate sim rooms(n=1) internal debriefing room(n=1) walled sim rooms(n=1) specialized space for pre-briefing(n=1) entrance offices(n=1)	"Doors are small. Ideally combine debriefing room with sim internal rooms/but short distance is beneficial (close). Function of the rooms don't need glassed, but stakeholders wanted that to reflect good reputation and open space to show capacity and show what is happening in the rooms. In general, a very nice design although the given constructional constraints. No space where you would do pre-briefing"
(7) *Ideality and optimality*			Ideal to meet needs(n=6)	"The solution may not be the perfect solution for a simulation lab, but it meets their needs in the given space, relatively small area, it is not a big center compared to other big one, but it covers all the major function of simulation"
(8) *Recommendations and expectations*			Near accessible storage independent simulation sustainable layout financially sustainable inclusive space aesthetically pleasing center continuous training for technicians in design focus on: (1) participants' flow (2) programs offered (3) accommodation capacity (4) flexibility (5) maturity Generate money: (1) offer certifications (2) coordination with other institutions Flexible area	"The flow considers the statics the image of AUB to represent good reputation and make a greater impression. The lab is useful on its own, to market the quality of education, bring in finances, bring outsiders, we have to compete at their level, so aesthetically it should be appealing"

Table 2 Hierarchal Organization of Thematic Analysis

B. Descriptive Analysis

Firstly, we introduce demographical data about participants involved in the study. All statistical data were calculated according to split file between participants that were involved in the design process of the new simulation facility at AUBMC and other simulation facilities in Lebanon (like the simulation lab at AUBMC). This treatment was done because we need to show the state of the old design at AUBMC compared to the new design as well exploring existing simulation experiences in other facilities. There were five participants (N=5) involved in the design process with design roles: 1 architect, 2 project consultants (CAE and SH Group), 1 simulation Program Director, and 1 Biomedical Engineer shown in Table 3 . While three participants (N=3) have administrative role (e.g. simulation coordinator, director) from other simulation facilities in academic or hospital institutions.

Role

Design_Involvement			Frequency	Percent	Valid Percent	Cumulative Percent
No	Valid	Administration	3	100.0	100.0	100.0
Yes	Valid	Design	5	100.0	100.0	100.0

Design Role

Design_Involvement			Frequency	Percent	Valid Percent	Cumulative Percent
No	Missing	System	3	100.0		
Yes	Valid	Architect	1	20.0	20.0	20.0
		CAE	1	20.0	20.0	40.0
		SH Group	1	20.0	20.0	60.0
		BME	1	20.0	20.0	80.0
		Simulation Program Director	1	20.0	20.0	100.0
		Total	5	100.0	100.0	

Table 3 Participants' Role and Design Role

The majority age was 40 to 45 years old, which accounted for 62.5% out of 8 participants, and our participants were 62.5% male and 37.5% female (shown in Figure 1).

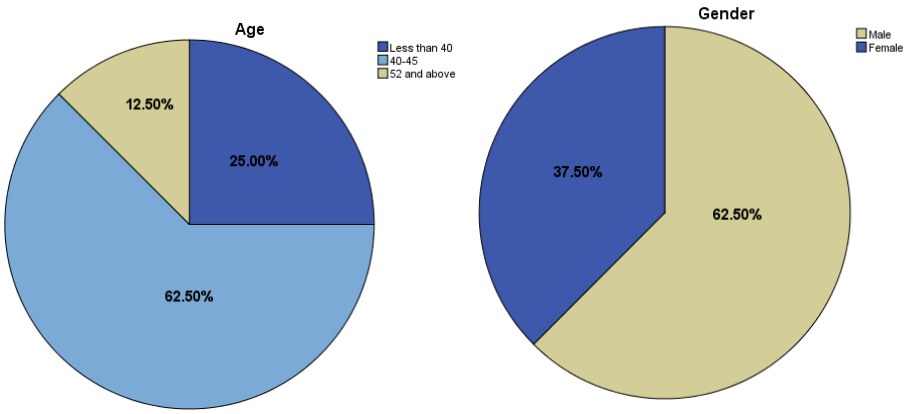


Figure 1 Participant's Age and Gender

Three participants from other simulation facilities are from nursing school. While participants involved in design were from different industry sectors Biomedical Engineer, Architect, Computer Engineer, and Medicine (20%, 20%, 40%, and 20% respectively).

Design_Involvement			Frequency	Percent	Valid Percent	Cumulative Percent
No	Valid	Nursing	3	100.0	100.0	100.0
Yes	Valid	BME	1	20.0	20.0	20.0
		Architect	1	20.0	20.0	40.0
		Computer Engineer	2	40.0	40.0	80.0
		Medicine	1	20.0	20.0	100.0
		Total	5	100.0	100.0	

Table 4 Participant's Education Field

For participants not involved in design, 1 participant who has experience less than 5 years, and 1 worked in the field for 26 years and above. 60% of participants involved in design have experience between 6 and 15 years in their field (as shown in Table 5).

Design_Involvement			Frequency	Percent	Valid Percent	Cumulative Percent
No	Valid	Under 5	1	33.3	33.3	33.3
		16-25	1	33.3	33.3	66.7
		26 and above	1	33.3	33.3	100.0
		Total	3	100.0	100.0	
Yes	Valid	6-15	3	60.0	60.0	60.0
		16-25	2	40.0	40.0	100.0
		Total	5	100.0	100.0	

Table 5 Participant's Years of Experience in the Field

25% of participants have 8 to 10 years of experience in simulation. But 25% of participants don't have direct experience in medical simulation (e.g. architect) because they are not simulation instructors shown in Figure 2 Years of Experience in Medical Simulation

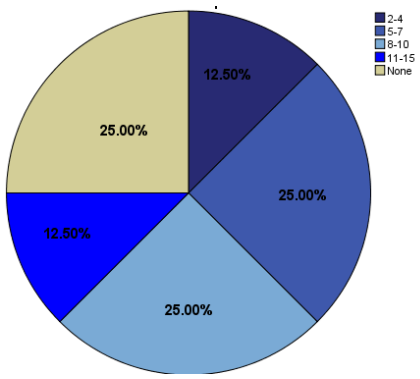


Figure 2 Years of Experience in Medical Simulation

All participants with simulation experience have simulation certifications, as 1 participant have CHSE (Certified Healthcare Simulation Educator) certification. Four participants involved in the design don't have simulation certification because there are not simulation educators, but they work in the field of simulation (e.g. Biomedical Engineer experienced in medical simulation equipment) (as shown in Table 6).

Design_Involvement			Frequency	Percent	Valid Percent	Cumulative Percent
No	Valid	CHSE	1	33.3	33.3	33.3
		IPE	1	33.3	33.3	66.7
		In progress	1	33.3	33.3	100.0
		Total	3	100.0	100.0	
Yes	Valid	CMS Simulation Instructor	1	20.0	20.0	20.0
		N.A	4	80.0	80.0	100.0
		Total	5	100.0	100.0	

Table 6 Participan's Simulation Certification

As Table 7 shows that one of the observed facilities is a center; it is the only medical simulation center in Lebanon other than the new center at AUBMC.

Design_Involvement			Frequency	Percent	Valid Percent	Cumulative Percent
No	Valid	Center	1	33.3	33.3	33.3
		Lab	2	66.7	66.7	100.0
		Total	3	100.0	100.0	
Yes	Valid	Center	5	100.0	100.0	100.0

Table 7 Facility Type

Two simulation facilities are accredited; one program is accredited by AHPGS (Accreditation Agency in Healthcare and Social Sciences) at AUBMC lab in other institution. Besides, the new center is in progress to gain accreditation after the official opening (as shown in Table 8).

Design_Involvement			Frequency	Percent	Valid Percent	Cumulative Percent
No	Valid	Other	2	66.7	66.7	66.7
		None	1	33.3	33.3	100.0
		Total	3	100.0	100.0	
Yes	Valid	In Progress	1	20.0	20.0	20.0
		N.A	4	80.0	80.0	100.0
		Total	5	100.0	100.0	

Other facility Accreditation

Design_Involvement			Frequency	Percent	Valid Percent	Cumulative Percent
No	Valid		1	33.3	33.3	33.3
		AAHPGS	1	33.3	33.3	66.7
		RCPSC	1	33.3	33.3	100.0
		Total	3	100.0	100.0	
Yes	Valid		5	100.0	100.0	100.0

Table 8 Facility Accreditation

Table 9 shows that only 1 simulation facility have satellite center to their hospital location, they can conduct simulation sessions in the hospital and control it from the simulation center.

Design_Involvement			Frequency	Percent	Valid Percent	Cumulative Percent
No	Valid	NO	2	66.7	66.7	66.7
		YES	1	33.3	33.3	100.0
		Total	3	100.0	100.0	
Yes	Valid	NO	2	40.0	40.0	40.0
		N.A	3	60.0	60.0	100.0
		Total	5	100.0	100.0	

Table 9 Availability of Satellite Center

Table 10 shows that two facilities not involved in design conduct in-situ simulation in the clinical environment or ER department and one facility don't conduct in-situ because it is only an educational institution.

Design_Involvement			Frequency	Percent	Valid Percent	Cumulative Percent
No	Valid	NO	1	33.3	33.3	33.3
		YES	2	66.7	66.7	100.0
		Total	3	100.0	100.0	
Yes	Valid	YES	1	20.0	20.0	20.0
		N.A	4	80.0	80.0	100.0
		Total	5	100.0	100.0	

Table 10 Conduct In-situ

For the quality and safety program in simulation facilities 33.3% follow hospital standards and 33.3% they follow the University standards (as shown in Table 11).

Design_Involvement			Frequency	Percent	Valid Percent	Cumulative Percent
No	Valid		1	33.3	33.3	33.3
		Hospital Standards	1	33.3	33.3	66.7
		University Standards	1	33.3	33.3	100.0
		Total	3	100.0	100.0	
Yes	Valid		4	80.0	80.0	80.0
		Hospital Standards	1	20.0	20.0	100.0
		Total	5	100.0	100.0	

Table 11 Quality and Safety Program

Table 12 shows that all simulation facilities in Lebanon provide multidisciplinary program. All program offerings (undergraduate, graduate courses, medicine school, pharmacy, pediatrics, nursing, health sciences program, pharmacy etc.)

Design_Involvement			Frequency	Percent	Valid Percent	Cumulative Percent
No	Valid	All	3	100.0	100.0	100.0
Yes	Valid	All	2	40.0	100.0	100.0
	Missing	System	3	60.0		
	Total		5	100.0		

Table 12 Type of Discipline Program

Besides, simulation facilities in Lebanon have various uses like classroom, skills proficiency, self-directed simulation learning, team simulation learning, and clinical practice as well 2 respondents provide certification in their facilities.

Students and professions can access the center or facility outside lab hours 100% and 40% for not involved and involved in design respectively (shown in Table 13).

Design_Involvement			Frequency	Percent	Valid Percent	Cumulative Percent
No	Valid	All	3	100.0	100.0	100.0
Yes	Valid	All	2	40.0	100.0	100.0
	Missing	System	3	60.0		
	Total		5	100.0		

Other Uses of Facility

Design_Involvement			Frequency	Percent	Valid Percent	Cumulative Percent
No	Valid	Certificates	2	66.7	66.7	66.7
		All When Requested	1	33.3	33.3	100.0
		Total	3	100.0	100.0	
Yes	Valid	All When Requested	1	20.0	100.0	100.0
	Missing	System	4	80.0		
	Total		5	100.0		

Facility Accessibility

Design_Involvement			Frequency	Percent	Valid Percent	Cumulative Percent
No	Valid	All	3	100.0	100.0	100.0
Yes	Valid	All	3	60.0	60.0	60.0
		N.A	2	40.0	40.0	100.0
		Total	5	100.0	100.0	

Accessible Outside Lab Hours

Design_Involvement			Frequency	Percent	Valid Percent	Cumulative Percent
No	Valid	YES	3	100.0	100.0	100.0
Yes	Valid	YES	2	40.0	40.0	40.0
		N.A	3	60.0	60.0	100.0
		Total	5	100.0	100.0	

Table 13 Facility Uses

Design_Involvement			Frequency	Percent	Valid Percent	Cumulative Percent
No	Valid	up tp 10 at a time	1	33.3	33.3	33.3
		up to 15 at a time	1	33.3	33.3	66.7
		up to 60 at a time	1	33.3	33.3	100.0
		Total	3	100.0	100.0	
Yes	Valid	up to 20 at a time	4	80.0	80.0	80.0
		up to 60 at a time	1	20.0	20.0	100.0
		Total	5	100.0	100.0	

Table 14 Facility Accommodation

33.3% of 3 facilities accommodate up to 10 people at a time in the facility. In the new center, 80% of respondents said that the new center can accommodate up to 20 students at a time and 20% responded up to 60 people at a time (as shown in Table 14).

Design_Involvement		N	Range	Minimum	Maximum	Mean	Std. Deviation
No	Number of Staff	3	5	1	6	2.67	2.887
	Valid N (listwise)	3					
Yes	Number of Staff	4	1	4	5	4.75	.500
	Valid N (listwise)	4					

Table 15 Human Resource at The Facility

Design_Involvement			Frequency	Percent	Valid Percent	Cumulative Percent
No	Valid	NO	2	66.7	66.7	66.7
		YES	1	33.3	33.3	100.0
		Total	3	100.0	100.0	
Yes	Valid	YES	3	60.0	60.0	60.0
		N.A	2	40.0	40.0	100.0
		Total	5	100.0	100.0	

Table 16 Staff Adequacy

Facilities not involved in design have an average staff of 2.67 which is up to 3 staff working in the facility, but there is a variation in number of staff in Lebanese simulation facilities st.D= 2.887. The new facility, have an average of 4.75 staff which is up to 5 staff expected to work in such a simulation facility, the variation is low among participants' response st.D= 0.5 (shown in Table 15). However, 66.7% of respondents said that staff are not adequate while 60% of participants involved in design said that staff is adequate (as shown in Table 16).

Design_Involvement		N	Range	Minimum	Maximum	Mean	Std. Deviation
No	Number_of_IT_BME	3	1.00	1.00	2.00	1.3333	.57735
	Valid N (listwise)	3					
Yes	Number_of_IT_BME	5	1.00	2.00	3.00	2.2000	.44721
	Valid N (listwise)	5					

Table 17 Number of Technical Staff

Among the staff in other Lebanese simulation facilities there is an average of 1.33 Biomedical Engineer, and the variations (st.D= 0.57) within participants is low. While in the new simulation center at AUBMC there is an average of 2.2 staff rounded to 3 staff and the variation is low among respondents is low st.d=0.447 (as shown in Table 17).

100% of participants responded that staff and technicians are trained on simulation hardware and software simulation system and equipment (shown in Table 18).

Design_Involvement			Frequency	Percent	Valid Percent	Cumulative Percent
No	Valid	YES	3	100.0	100.0	100.0
Yes	Valid	YES	5	100.0	100.0	100.0

Table 18 Staff Training Needs

Table 19 shows that there is a minimum of 110m^2 simulation facility and maximum of 937 m^2 facility one of the largest simulation facility in Lebanon st.D= 434.9 shows a high variation among facilities. The new simulation facility at AUBMC have an average area= 600 m^2.

Design_Involvement		N	Range	Minimum	Maximum	Mean	Std. Deviation
No	Facility_Area	3	827	110	937	445.67	434.921
	Valid N (listwise)	3					
Yes	Facility_Area	5	0	600	600	600.00	.000
	Valid N (listwise)	5					

Table 19 Facility Area

The number of rooms in other facilities ranges from 1 room and up to 19 rooms st.D= 9.29 shows the high variation among Lebanese facilities. The new simulation center have an average number of rooms= 10.6 with st.D= 0.58 low variation among respondents answers (as shown in Table 20).

Design_Involvement		N	Range	Minimum	Maximum	Mean	Std. Deviation
No	NumberOfRooms	3	18	1	19	8.67	9.292
	Valid N (listwise)	3					
Yes	NumberOfRooms	5	1	10	11	10.60	.548
	Valid N (listwise)	5					

Table 20 Number of Rooms

Table 21 shows that 66.7% of simulation facilities in Lebanon have natural light in their centers, and 33.3% don't have enough natural light only specific rooms (e.g. offices). 80% shows that there is natural light at the new center AUBMC but not all rooms (as shown in Table 22).

Design_Involvement			Frequency	Percent	Valid Percent	Cumulative Percent
No	Valid	YES	2	66.7	66.7	66.7
		Not all rooms	1	33.3	33.3	100.0
		Total	3	100.0	100.0	
Yes	Valid	YES	1	20.0	20.0	20.0
		Not all rooms	4	80.0	80.0	100.0
		Total	5	100.0	100.0	

Table 21 Existence of Natural Light

Design_Involvement			Frequency	Percent	Valid Percent	Cumulative Percent
No	Valid	Multipurpose	3	100	100	100
		Total	3	100.0	100.0	
Yes	Valid	Multipurpose	4	80.0	80.0	80.0
		Multipurpose and Specialized	1	20.0	20.0	100.0
		Total	5	100.0	100.0	

Table 22 Function of Rooms

Table 23 shows that 100% of simulation facilities in Lebanon utilize multipurpose rooms that can be used for any program/course purposes, and 80% of participants involved in design said that the rooms are multipurpose.

Design_Involvement			Frequency	Percent	Valid Percent	Cumulative Percent
No	Valid	Inpatient and Outpatient	1	33.3	33.3	33.3
		Beside each other	1	33.3	33.3	66.7
		Stations	1	33.3	33.3	100.0
		Total	3	100.0	100.0	
Yes	Valid	Central and 1 Peripheral	5	100.0	100.0	100.0

Table 23 Location of Rooms

Rooms are located different among sim facilities in Lebanon. 1 facility has two areas, the outpatient area is composed of 8 outfitted clinics which mimic real physical assessment rooms, and these rooms are peripherally located with a central classroom in between to combine all practitioners together. The inpatient area is a large open space with 7 cubicles on the periphery separated by curtains and 2 peripheral rooms that can be accessed from the inpatient area. In one facility the rooms are located next to each other, and in 1 facility there are no rooms, it is an open space area with stations or cubicles separated by curtains. In the new sim facility design 100% said that the rooms are centrally located with peripheral rooms around the central functions, besides, 100% said that rooms are separated with sound proved walls (as shown in Table 24) 66.7% have both curtains and walls separation but only 1 facility have some level of sound proving walls (as shown in Table 25).

Design_Involvement			Frequency	Percent	Valid Percent	Cumulative Percent
No	Valid	Curtains	1	33.3	33.3	33.3
		Both	2	66.7	66.7	100.0
		Total	3	100.0	100.0	
Yes	Valid	walls	5	100.0	100.0	100.0

Table 24 Rooms Separation Material

Design_Involvement			Frequency	Percent	Valid Percent	Cumulative Percent
No	Valid	NO	2	66.7	66.7	66.7
		YES	1	33.3	33.3	100.0
		Total	3	100.0	100.0	
Yes	Valid	YES	4	80.0	80.0	80.0
		N.A	1	20.0	20.0	100.0
		Total	5	100.0	100.0	

Table 25 Sound Proofing

As shown in Table 26, 100% of sim facilities in Lebanon have linear flow shape around the rooms, they move from one room to another linearly. For the new center, 40% of participants consider a circular flow around sim rooms while 60% consider a flow

with combination of circular and star shape flow because of the circular loop corridor that can access to central functions as well as side function which reflects a star shape. All participants in this study consider the flow as a highly important consideration in design.

100% of other facilities perform OSCEs (Objective Structured Clinical Examination) (as shown in Table 27). while the efficiency of setup various. 1 facility has a highly acceptable setup and flow, and 1 has a limited setup for such purposes. Besides, the new facility performs OSCEs as 40% of participants responded that the setup and flow is highly acceptable.

Design_Involvement			Frequency	Percent	Valid Percent	Cumulative Percent
No	Valid	Linear	3	100.0	100.0	100.0
Yes	Valid	Circular	2	40.0	40.0	40.0
		Combination of circular and star shape	3	60.0	60.0	100.0
		Total	5	100.0	100.0	

Importance of Flow

Design_Involvement			Frequency	Percent	Valid Percent	Cumulative Percent
No	Valid	Highly important	3	100.0	100.0	100.0
Yes	Valid	Highly important	5	100.0	100.0	100.0

Table 26 Flow Shape

Design_Involvement			Frequency	Percent	Valid Percent	Cumulative Percent
No	Valid	YES	3	100.0	100.0	100.0
Yes	Valid	YES	2	40.0	100.0	100.0
	Missing	System	3	60.0		
	Total		5	100.0		

Setup for OSCEs

Design_Involvement			Frequency	Percent	Valid Percent	Cumulative Percent
No	Valid	Highly acceptable	1	33.3	33.3	33.3
		Acceptable	1	33.3	33.3	66.7
		Limited	1	33.3	33.3	100.0
		Total	3	100.0	100.0	
Yes	Valid	Highly acceptable	2	40.0	40.0	40.0
		N.A	3	60.0	60.0	100.0
		Total	5	100.0	100.0	

Table 27 OSCEs at The Facility and state of the Setup for such purposes

Table 28 show that there is an average of 2 simultaneous sessions that happen in other facilities, while a higher average 3.4 at the new AUBMC center. The st.d= 0.54 shows a low variation in the respondents' answers.

Design_Involvement		N	Range	Minimum	Maximum	Mean	Std. Deviation
No	Num_of_Simultaneous_Sessions	3	3	0	3	2.00	1.732
	Valid N (listwise)	3					
Yes	Num_of_Simultaneous_Sessions	5	1	3	4	3.40	.548
	Valid N (listwise)	5					

Table 28 Number of Simultaneous Scenarios

As show in Table 29 Existence of Control Rooms 66.7% of facilities don't have control room and usually observation take place within the same room. while 1 facility has two control rooms one central that can observe two control rooms and one external high-tech with no observation windows, only observing from PCs. 100% of participants involved in design said that there is two control rooms, but 40% consider it as a central control room to the sim rooms and 60% consider 1 common central control room and 1 small peripheral control room that can observe only one peripheral sim room (as shown in Table 31).

Design_Involvement			Frequency	Percent	Valid Percent	Cumulative Percent
No	Valid	NO	2	66.7	66.7	66.7
		YES	1	33.3	33.3	100.0
		Total	3	100.0	100.0	
Yes	Valid	YES	5	100.0	100.0	100.0

Table 29 Existence of Control Rooms

Design_Involvement		N	Range	Minimum	Maximum	Mean	Std. Deviation
No	Number_of_Control_Rooms	3	2	0	2	.67	1.155
	Valid N (listwise)	3					
Yes	Number_of_Control_Rooms	5	0	2	2	2.00	.000

Valid N (listwise)	5	

Table 30 Number of Control Room

Design_Involvement			Frequency	Percent	Valid Percent	Cumulative Percent
No	Valid	Within the sim room	2	66.7	66.7	66.7
		Both central and peripheral	1	33.3	33.3	100.0
		Total	3	100.0	100.0	
Yes	Valid	Central to sim rooms	2	40.0	40.0	40.0
		Both central and peripheral	3	60.0	60.0	100.0
		Total	5	100.0	100.0	

Table 31 Location of Observation/Control Room

Control rooms in Lebanese simulation facilities can accommodate an average of 3 people per control room and there is a high variation among studied facilities st.d= 1. For the new center, the average accommodation of people is 3.6 rounded up to 4 people/control room, the st.d=0.548 is low among participants' responses (as shown in Table 32).

Design_Involvement		N	Range	Minimum	Maximum	Mean	Std. Deviation
No	Control_Room_Capacity	3	2	2	4	3.00	1.000
	Valid N (listwise)	3					
Yes	Control_Room_Capacity	5	1	3	4	3.60	.548
	Valid N (listwise)	5					

Table 32 Accommodation of a Control Room

Debriefing room is a core function of simulation where instructors provide pre-briefing of the scenario and debriefing of the simulation session for assessment and learning. 33.3% of Lebanese simulation facilities don't have debriefing room and it occurs within the sim room as shown in Table 33. while 66.7% have debriefing rooms. 1 facility located the debriefing room very close to the sim room. For the new facility, as shown in 100% responded that there are 2 debriefing rooms that can be combined into 1 large debriefing room. 100% of participants said that the debriefing room is located very close to sim rooms (as shown in Table 34).

Design_Involvement			Frequency	Percent	Valid Percent	Cumulative Percent
No	Valid	0	1	33.3	33.3	33.3
		1	2	66.7	66.7	100.0
		Total	3	100.0	100.0	
Yes	Valid	2 rooms can be joined to 1	5	100.0	100.0	100.0

Table 33 Number of Debriefing Rooms

Design_Involvement			Frequency	Percent	Valid Percent	Cumulative Percent
No	Valid	Within the sim room	2	66.7	66.7	66.7
		very close to sim room	1	33.3	33.3	100.0
		Total	3	100.0	100.0	
Yes	Valid	very close to sim room	5	100.0	100.0	100.0

Table 34 Location of the Debriefing Room

There is an average of 1.67 storage rooms in simulation facilities which is up to 2 storage rooms the st.d=0.577 shows that there are close responses among participants. The new facility sows to have one storage room shown in Table 35. shows that 33.3% said that the storage is not sufficient because dispersed closets and shared storage room with others for other purposes. 5 participants involved in design they expect an enough storage after functionality because the space was very well planned for their needs.

Design_Involvement		N	Range	Minimum	Maximum	Mean	Std. Deviation
No	Number_of_Storage_Room	3	1	1	2	1.67	.577
	Valid N (listwise)	3					
Yes	Number_of_Storage_Room	5	0	1	1	1.00	.000
	Valid N (listwise)	5					

Efficiency of Storage

Design_Involvement			Frequency	Percent	Valid Percent	Cumulative Percent
No	Valid	Low	1	33.3	33.3	33.3
		High	2	66.7	66.7	100.0
		Total	3	100.0	100.0	
Yes	Valid	High	5	100.0	100.0	100.0

Table 35 Number of Storage Rooms and its Efficiency

Table 36 shows that 1 storage room is located internal to sim rooms that are very close to sim or functional rooms, 1 storage room have no access from sim room which

means they need to walk a long distance to get their medications, equipment, or tools, and 1 storage room is located directly beside the inpatient room. While the storage room in the new sim center at AUBMC is internally located to sim rooms.

Design_Involvement			Frequency	Percent	Valid Percent	Cumulative Percent
No	Valid	Internal to sim rooms	1	33.3	33.3	33.3
		no access from sim room	1	33.3	33.3	66.7
		Beside inpatient room	1	33.3	33.3	100.0
		Total	3	100.0	100.0	
Yes	Valid	Internal to sim rooms	5	100.0	100.0	100.0

Table 36 Location of Storage Room

Design_Involvement			Frequency	Percent	Valid Percent	Cumulative Percent
No	Valid	create one	3	100.0	100.0	100.0
Yes	Valid	create one	2	40.0	40.0	40.0
		N.A	3	60.0	60.0	100.0
		Total	5	100.0	100.0	

Table 37 Existence of Wet Moulage

As shown in Table 37 all simulation facilities don't have dedicated room or space for wet moulage (e.g. preparing blood) they usually create a wet moulage area anywhere where available when needed.

2 facilities don't have reception area and only 1 facility has a reception area, while the new simulation center has a reception area (as shown in Table 38).

Design_Involvement			Frequency	Percent	Valid Percent	Cumulative Percent
No	Valid	NO	2	66.7	66.7	66.7
		YES	1	33.3	33.3	100.0
		Total	3	100.0	100.0	
Yes	Valid	YES	5	100.0	100.0	100.0

Table 38 Existence of a Reception Area

For the waiting area, only 1 facility have a waiting area for either SP's (standardized patients) or for visitors while two facilities have shared waiting area with

others in the floor not specialized for SP's. The new facility as the 5 respondents provide that there is waiting area. Besides, in one of the facilities with shared waiting area there are no lockers for the SP's, while 2 facilities have lockers with the sim room or within the waiting room. The new facility has lockers in the bathrooms for both male and female.

Design_Involvement			Frequency	Percent	Valid Percent	Cumulative Percent
No	Valid	YES	1	33.3	33.3	33.3
		Shared	2	66.7	66.7	100.0
		Total	3	100.0	100.0	
Yes	Valid	YES	5	100.0	100.0	100.0

Lockers

Design_Involvement			Frequency	Percent	Valid Percent	Cumulative Percent
No	Valid	NO	1	33.3	33.3	33.3
		YES	2	66.7	66.7	100.0
		Total	3	100.0	100.0	
Yes	Valid	YES	5	100.0	100.0	100.0

Table 39 Existence of Waiting Area and Lockers

Design_Involvement		N	Range	Minimum	Maximum	Mean	Std. Deviation
No	Number_of_Offices	3	3	0	3	1.00	1.732
	Valid N (listwise)	3					
Yes	Number_of_Offices	5	0	2	2	2.00	.000
	Valid N (listwise)	5					

Design_Involvement		N	Range	Minimum	Maximum	Mean	Std. Deviation
No	Accomodation_of_Offices	3	3	1	4	2.00	1.732
	Valid N (listwise)	3					
Yes	Accomodation_of_Offices	5	0	5	5	5.00	.000
	Valid N (listwise)	5					

Table 40 Number of Offices and Capacity

There is an average number of one office in other simulation facilities that can accommodate an average of 2 staff although there is a high variation st.d=1.73 because some simulation facilities don't have offices but only working desks. While the new simulation facility contains 2 offices and there is no variation between respondents. The 2

offices can accommodate up to an average of 5 staff with st.d= 0 among respondents (as shown in Table 40).

Table 41 33.3% have ‘CAE’ simulation system, 33.3% have ‘Laerdal’ simulation system. The new facility has a ‘CAE’ sim system. In shows that audiovisual equipment is ‘CAE’ in one of the facilities, ‘Laerdal’ in other facility, and facility have a combination of ‘Gauamrd’ and ‘Laerdal’. All these companies are the pioneers in medical simulation.

Design_Involvement			Frequency	Percent	Valid Percent	Cumulative Percent
No	Valid	CAE	1	33.3	50.0	50.0
		Laerdal	1	33.3	50.0	100.0
		Total	2	66.7	100.0	
	Missing	System	1	33.3		
	Total		3	100.0		
Yes	Valid	CAE	4	80.0	100.0	100.0
	Missing	System	1	20.0		
	Total		5	100.0		

Table 41 Simulation System Brand

Table 42 the audiovisual brand in simulation facilities match with the simulation system they invest in. 5 participants responded as ‘CAE’ audiovisual as well other facility have ‘CAE’ audiovisual. Only 1 facility have ‘Laerdal’ audiovisual and 1 facility have a combination of ‘Gaumard’ and ‘Laerdal’.

Design_Involvement			Frequency	Percent	Valid Percent	Cumulative Percent
No	Valid	CAE	1	33.3	33.3	33.3
		Laerdal	1	33.3	33.3	66.7
		Gaumard and Laerdal	1	33.3	33.3	100.0
		Total	3	100.0	100.0	
Yes	Valid	CAE	5	100.0	100.0	100.0

Table 42 Audiovisual Brand

Simulation facilities place their audiovisuals (cameras, microphones, and speakers) in various locations. 2 out of 3 facilities they locate their cameras for observation to the control room, at the head of the manikin in order to capture a full view on the manikin. While 1 facility has cameras placed at the head in cubicles, in clinics they have perpendicular cameras (attached to the ceiling) above the SP (patient) and the practitioner, and corner cameras. Besides, 1 facility has separate microphones from the camera located above the bed, while 2 facilities depend on the sound within the camera. The new facility as 3 participants responded that they have microphone above each bed attached to the ceiling (as shown in Table 43 and Table 44).

Design_Involvement			Frequency	Percent	Valid Percent	Cumulative Percent
No	Valid	at the head	2	66.7	66.7	66.7
		All	1	33.3	33.3	100.0
		Total	3	100.0	100.0	
Yes	Valid	All	3	60.0	100.0	100.0
	Missing	System	2	40.0		
	Total		5	100.0		

Table 43 Camera's Location

Design_Involvement			Frequency	Percent	Valid Percent	Cumulative Percent
No	Valid	above bed	1	33.3	33.3	33.3
		within the camera	2	66.7	66.7	100.0
		Total	3	100.0	100.0	
Yes	Valid	above bed	3	60.0	60.0	60.0
		N.A	2	40.0	40.0	100.0
		Total	5	100.0	100.0	

Table 44 Microphones Placement

Table 45 only 1 facility out of the three facilities, don’t have preventive maintenance schedule program to follow but they usually do weekly checkups on manikins and in case of any breakdown they call the technicians in the IT department. While 2 facilities follow preventive maintenance program as requested by the consulting company, one of them have monthly maintenance and the other yearly maintenance. Besides, the new facility schedule preventive maintenance program on monthly basis.

Design_Involvement			Frequency	Percent	Valid Percent	Cumulative Percent
No	Valid	NO	1	33.3	33.3	33.3
		YES	2	66.7	66.7	100.0
		Total	3	100.0	100.0	
Yes	Valid	YES	3	60.0	60.0	60.0
		N.A	2	40.0	40.0	100.0
		Total	5	100.0	100.0	

Design_Involvement			Frequency	Percent	Valid Percent	Cumulative Percent
No	Valid	Weekly	1	33.3	33.3	33.3
		Monthly	1	33.3	33.3	66.7
		Yearly	1	33.3	33.3	100.0
		Total	3	100.0	100.0	
Yes	Valid	Monthly	2	40.0	40.0	40.0
		N.A	3	60.0	60.0	100.0
		Total	5	100.0	100.0	

Table 45 Preventive Maintenance Needs

Each manikin requires cleaning in order to avoid germs on its surface. As 3 respondents said that the cleaning task is accomplished by the simulation coordinator. While in the new facility 2 participants said that technicians are responsible for cleaning tasks (as shown in Table 46).

Design_Involvement			Frequency	Percent	Valid Percent	Cumulative Percent
No	Valid	Simulation Coordinator	3	100.0	100.0	100.0
Yes	Valid	Technician	2	40.0	40.0	40.0
		N.A	3	60.0	60.0	100.0
		Total	5	100.0	100.0	

Table 46 Cleaning Tasks

Table 47 shows that 1 participant among other facilities said that the facility is not ideal, 1 participant considers their simulation facility is ideal, and 1 participant considers the sim lab is ideal to meet the program needs. While for the new facility, 20% of participants involved in design consider the new design ideal, and 60% consider the new design ideal to meet program needs.

Design_Involvement			Frequency	Percent	Valid Percent	Cumulative Percent
No	Valid	NO	1	33.3	33.3	33.3
		YES	1	33.3	33.3	66.7
		Ideal to meet program needs	1	33.3	33.3	100.0
		Total	3	100.0	100.0	
Yes	Valid	YES	1	20.0	20.0	20.0
		Ideal to meet program needs	4	80.0	80.0	100.0
		Total	5	100.0	100.0	

Table 47 Ideality/optimality of the Facility Design

CHAPTER V

DISCUSSIONS AND RECOMMENDATIONS

A. Design Approach and Framework

Healthcare facility design is recently focusing on new design approach other than the healthcare design standards. Healthcare is moving towards 'evidence-based design' (k.Miller et al., 2016) which is an effective approach to ensure the efficiency of healthcare processes, safe environment for users, and higher staff performance. 'Evidence-based design' was implemented during the design process of the new simulation center at AUBMC. A combination of professional groups including stakeholders from healthcare professionals and specifically simulation experts as well personnel outside the healthcare discipline (e.g. engineering, architect, biomedical engineers etc.) in order to solve the design challenges from different perspectives and based on their experience in simulation and operation performance.

The user is seen as an input or resource which is included early in the design process. The healthcare simulation environment is an integrated system of healthcare professions, end users (e.g. staff), equipment and people involved in the technology work, consultants, and contractors. During this study, we were aware that those people bring different perspectives of knowledge and attitude towards designing lean and innovative physical architectural space, effective experience, and organizational reputation.

Therefore, a design framework (as shown in Figure 3) was created to illustrate four design aspects/inputs of the simulation facility, the importance of involving diverse stakeholders' perspectives, and how to integrate these perspectives into design.

1. ***Architectural physical design:***

where the architect is knowledgeable about the rooms' area, layout and flow, light, space, safety etc. and project's time management and budget.

2. ***Simulation operation design:***

was a crucial input to the design process, where faculty users and simulation coordinators elaborate about the simulation operational process like communication within groups, standardized patient and students flow, and program and accommodation needs.

3. ***Technological space:***

where AV and simulation design consultants, and IT consultants provide best simulators and AV system that meets such an advanced technological facility.

4. Organizational goals:

where facility managers and administrators are the owners' representatives to ensure smooth process and construction, translated vision into function, and reputation and experience.

According to the AUBMC simulation center experience, a successful new simulation facility was achieved by integrating the four aspects/inputs discussed involving the stakeholders and users' perspectives with various thoughts and attitudes.

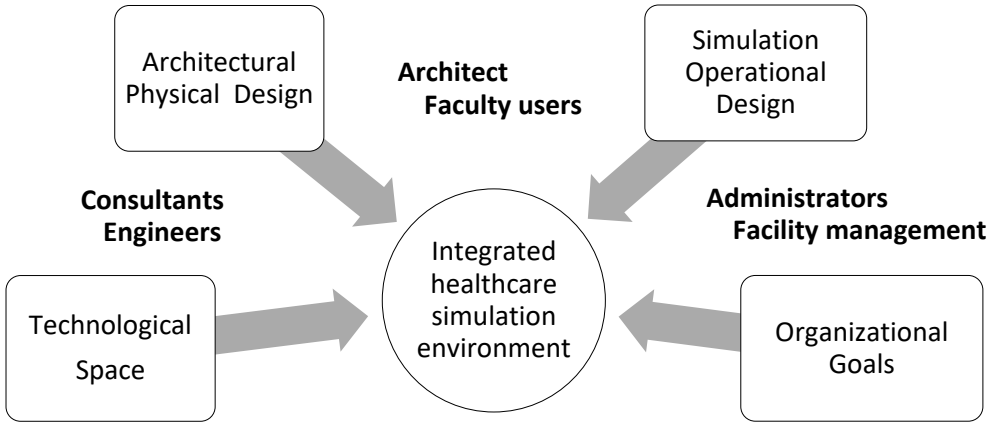


Figure 3 Strategy Framework for Designing Simulation Facilities

B. Design Process

Throughout the design process for a medical simulation facility there were various phases to consider (as shown in Figure 3). **Error! Reference source not found.** identifies d esign phases and how the process evolved:

1. Background:

a. Needs assessment:

during the study at AUBMC, we found gaps and needs that should be improved in the simulation lab to meet the institution goals and needs, due to various constraints such as lab space and structure, and human resource shortage. Thus, the following phases were developed to address the AUBMC needs.

b. Identify project's scope and objectives:

the findings of the study at the AUBMC simulation center were discussed based on the identification of the three main objectives/scope of the center prior to design and layout planning:

- Integrate a state-of-the-art simulation center that meets the needs of learners on all level from students to faculty members.
- The simulation lab becomes financially independent.
- Meet accreditation standards in the architectural design, organization of space, and simulation learning program. The AUBMC simulation center aims to get accredited, thus, accreditation was part of the entire process and it was considered in each step of the center design.

2. Implementation and Project Planning:

a. Establish simulation facility design team***:***

it is an initial important step, where people from different disciplines and backgrounds integrate in the simulation process design (as discussed in Figure 3).

b. Bid -Build Contracts and Equipment Procurement:

after the project was conceptualized by the institution, various consulting companies bid-in the project. Each company proposes a plan based on the objectives, and the technical and economic feasibility. A detailed design was carried out in stages and they provided complete drawings, specifications and detailed cost estimates. This phase was long; stakeholders ensured building a contract with a reputational company with high-quality and cost-effective simulators and simulation system.

c. Create design drawings and proposals:

simulation consultants proposed design drawings to the design team. The planning and designing phase took eight months to come up with the final design and layout because of some design constraints in pre-constructed foundations in the floor. The building was already pre-designed before planning for simulation and then each floor was allocated to a specific function. It was a challenge for consultants to cope with various opinions in the team, but the design team made the best of this space within the given space constructional constraints.

d. Finalize the design and startup the project:

it is the final step in the process, where contractors were given access to the site to proceed, and architects and project managers oversee the construction process.

The overall design process phases are the underlying study in which the researchers monitored the whole design process from the background to the implementation and methods of the design.

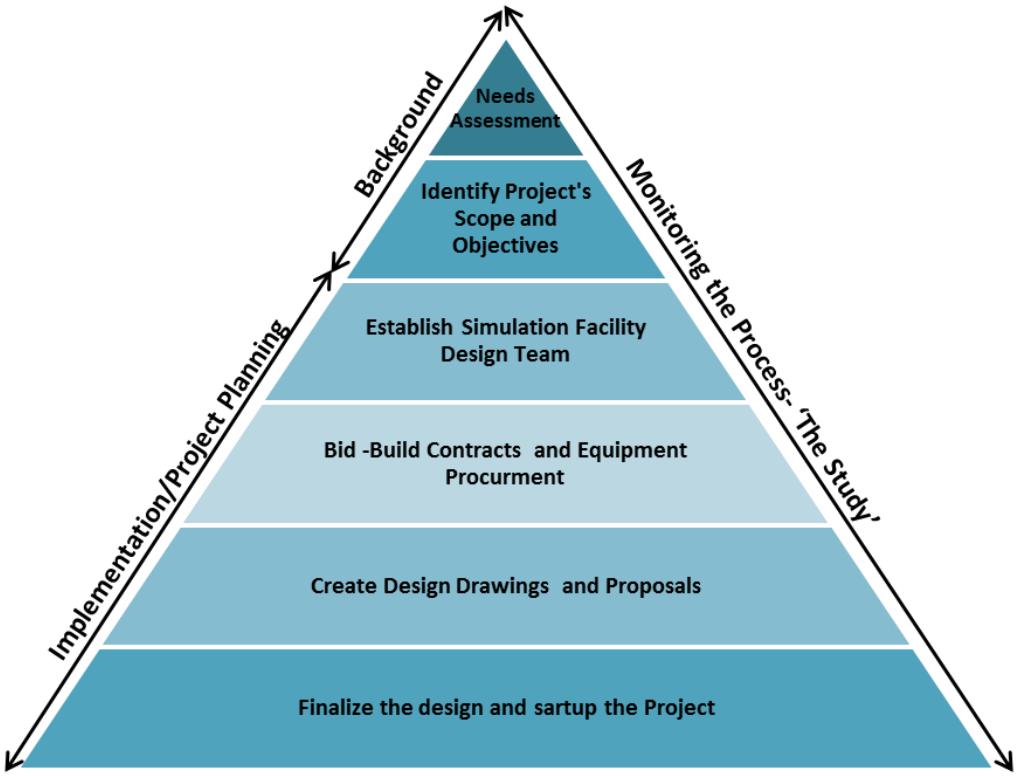


Figure 4 Design Process Phases and Flow

This study was an exploratory case study of the design of the simulation center at an academic hospital; the AUBMC simulation center. We aim to provide guidelines for

planning a physical space integrated with high technological environment. Structuring simulation functions should mimic a real environment with optimal learning environment while meeting the program needs, and the learners and instructors' satisfaction and experience. Structuring, zoning, and choosing the preferred simulation functions is not an intuitive process, it is a complex pragmatic long process. Establish meaningful relationships between the rooms or functions to meet the needs of both real healthcare environment and learning technical environment.

The results showed; based on the stakeholders' perspective; that the ideal simulation center layout and design for a 600 m^2 center within the given space constraints includes (as shown in Table 48):

Circular flow
Five multi-purpose simulation rooms
Central control room
Flexible and friendly working area
Flexible debriefing rooms
Administrative reception with waiting area
Storage areas
Utility rooms

Table 48: Functions of the AUBMC Simulation Center Design

Therefore, the intent of this research was to come up with design guidelines for further designers and healthcare institutions. Based on the results, the following are the recommended guidelines to take into consideration while designing a simulation center:

C. Organization of Space

1. Rooms' location and flow:

There are various flow shapes to consider in the center's layout (as shown in Figure 5):

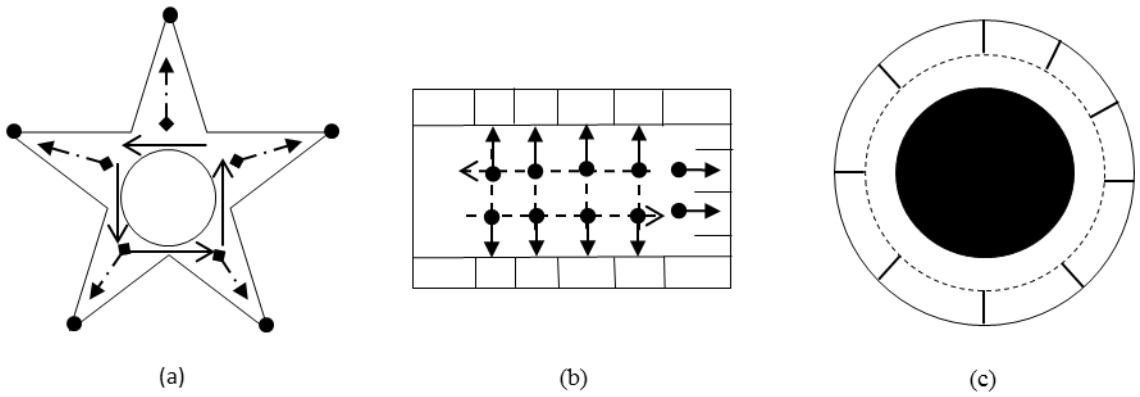


Figure 5 a b and c: Different flow shapes for a simulation center layout. Figure 5(a) shows a combination of circular flow and star shape. Figure 5 (b) shows a rectangular linear flow. Figure 5 (c) shows a circular plan flow.

- Case 1: The combination of *Circular flow with star shape* (as shown in Figure 5a); the space contains central functions and functions around that ensures a circular flow around those functions.

- Case 2: Unlike the combination of circular flow and star shape, the rectangular flow (as shown in Figure 5b) moving linearly from one room to another leads to potential intersections between learners affecting badly the simulation efficiency; due to high redundancy and interruptions.
- Case 3: Perfect circular plan flow (as shown in Figure 5c) means having peripheral functions or spaces with a central observational vantage point, then all the interior points are visible to all other peripheral functions. This case is not perfectly efficient for simulation center because learners meet in central points. However, if there is a central barrier or block, then the circular flow works efficiently because learners cannot see across the block.

The guidelines regarding rooms' zoning and structuring is to have centrally located simulation rooms with circular flow and functions around these rooms; the AUBMC center follows case 1. It was an optimal approach within the given space and space constraints at the AUBMC simulation center.

The AUBMC center was designed with several corridors around the functional rooms. This approach was implemented because it provides minimal intersections between practitioners and low redundancy to ensure efficient simulation operation with less wasted travel time. Simulation rooms were designed as big as in real life and there is proximity between rooms to apply sequential flow (from one scenario to the next in sequence). In order to avoid high noise levels that lead to learners' distraction consider having sound-proved walls.

Before executing the center's layout and flow, there are basic aspects to consider while designing the layout of a simulation center. (a) Participants' and users' flow between the rooms, (b) facility capacity and accommodation, and (c) equipment and staff flow are highly important. Students entering the center should not meet with the group who already practiced the scenario; in case of utilizing simultaneous scenarios. It is better for participants not to meet with standardized patients (actors) in order to avoid incorrect pre-judgement of the scenario happening.

Additionally, ensure a lean flow between simulation rooms through having accessible doors in between. For example, the accessible doors from the control room to all sim rooms around help decrease intersections and travel time. Although, the number of doors were optimized to decrease cost and increase space utility. Door placements or entry placements need to be thought out, taking into consideration the functionality and practicality of each room.

Only one sim room is located peripherally in the back-seen area which can be utilized either as NICU (Newborn Intensive Care Unit) or LDR (Labor, Delivery, Recovery room), because such type of rooms can work simultaneously with other scenarios and can run independently.

Additionally, ensure that the corridors and doors are flexible and functional to accommodate the expected number of students per group, and the movement of stretchers and large equipment. Especially while implementing simultaneous scenarios (more than one scenario happening at a time) and OSCEs (Objective Simulation Clinical

Examination), because it is important to ensure formative assessment while meeting international requirements with efficient flow and functionality.

2. Function of Rooms:

the AUBMC simulation center contains emergency room (ER), operating room (OR), recovery room or ICU (intensive care unit), NICU or LDR, and the multipurpose room. All rooms are adaptable to change from an inpatient room (supplied with all required gas outlets, such as O_2, CO_2, N_2…) to outpatient room (like clinics) and for various purposes. The center ensured having *multipurpose rooms* (generic rooms) that can be used for various purposes and scenarios because it was a one way of optimizing space. Ensure flexibility in the center to facilitate functionality. This can be translated by having a moveable folding wall between the ER and the OR room, to combine it into larger room for larger capacity and for different purposes.

In a simulation center design, suggest that all spaces are potential learning and teaching spaces. The right-side corridor contains linear desks for part-task trainers used for technical clinical skills. The multipurpose room as well is used for part-task trainers to avoid high sound levels in the corridor and for future expansions into virtual reality (VR) and artificial intelligence (AI).

Initially, it is difficult to choose the required simulation rooms in a simulation center, but while designing the center shortlist the functional simulation rooms that accommodate multi-disciplinary groups in the in-situ. For example, the in-situ (e.g.

emergency room) can accommodate a multi-disciplinary group of nurses, anesthesiologists, attending physicians, physical therapists and others.

Secondly, ensure a space that can serve multiple clinical/hospital environments. Utilizing multipurpose rooms optimizes space while meeting multiple needs and accommodating several discipline and groups, simply by changing the setup of the medical equipment, machines, furniture (e.g. emergency trolley, waste can, anesthesia trolley, Mayo tool, infant reanimation table, birthing bed etc.).

3. Control/Observation Rooms

One of the core functions in simulation is a control room where instructors observe and assess practitioners. Our center contains one *Shared-central control room* and one small peripheral control room. The centrally located observation room is accessible to many (4 rooms) simulation rooms within one room, through a one-way window to each room to provide an overall scenario view. It has also an accessible door to the storage room to decrease traveling time of instructors in case they need any equipment or medication.

Shared-central control room is an optimal choice because it decreases space utilization for same purpose, expenses and resources (e.g. instructors and equipment), and increases observers' simulation experience. For example, it is feasible for one instructor to observe multiple simulation scenarios.

Although, additional peripheral small control room was added for the purpose of controlling sound level and for simulation rooms that can work independently (e.g. NICU can have an independent scenario from the ER or OR).

It is feasible not to include a control room in the center due to the existence of portable advanced audiovisual system; that functions anywhere and at any time. But this will reduce a good simulation experience for instructors and increase interference.

4. Debriefing Rooms

Debriefing is a central core in simulation to ensure empirical learning and rigorous assessment (Abatzis and Littlewood, 2015). In our center, there are two flexible debriefing rooms which can be combined into larger debriefing room because of a folding wall between the two rooms. Larger room is needed for expected conferences, certifications, special course, or larger groups visiting the center etc.

Both rooms can accommodate between 20-25 people. While each room is set up as a meeting setting in order to facilitate group discussions and open integrative session to ensure a state of learning and assessment environment, the rooms are furnished with central moveable tables and chairs for alternative set ups when needed; for example, change for a separate setting or for a traditional class setting.

Both debriefing rooms are located peripherally to other simulation rooms ensuring short distance between the debriefing room and the simulation room. It is better to locate the debriefing room very close to the exit of a simulation room or adjacent to it, to decrease

the travel distance between these rooms in order to avoid intersection with another learner group.

A debriefing room is equipped with high technological equipment; LCDs, desktop PC and speakers to review, present and share what happened in the scenario to ensure the state-of-the-art of simulation learning environment, and whiteboards to make notes, draw charts etc. During the design planning phase, also consider constructing electrical outlets for power, data, phone lines etc. and include a cabinet for storage. These key considerations are highly important because the debriefing room is the primary space for simulation learning.

It is important to have a flexible debriefing room with high accommodation to meet various needs and expansions, such as seminars, certifications, courses, meetings etc. the number of debriefing rooms and their capacity should be at least the same as the number of simulation rooms. Nonetheless, in case of space limitation and small area an in-room debriefing can be implemented because of the accessibility of a live streaming system.

5. Storage Spaces

One of the daily challenges in simulation centers is storage. Storage is not always sufficient, thus, while designing a simulation center consider storage space based on the center/program needs and the number of equipment utilized in the center. It must fit a

stretcher, part-task trainers and medical equipment, although the center can include a multipurpose room or specialized area for part task trainers.

The AUBMC simulation center contains one big sufficient storage room that is accessible from the back seen area and from the *shared-central control room*. The storage room is located internally to other simulation functions on the side of the back seen area; where instructors can access it from the control room for easy and fast pickups. It is crucial to have accessible storage for educators while it is hidden from the public area to ensure fewer intersections between learners and practitioners and to control the accessibility to the storage room by any unauthorized person.

The storage room must be as large as any other simulation room in the center to fit all the equipment and stretchers. It is important to ensure a flexible storage room with moveable shelves; not fixed, drawers and cabinets; the area will reflect a larger flexible and adaptable space for any potential change.

Additionally, consider dead areas and corners for storage. In our center, the dead space between the columns in the back seen corridor is used to store medical equipment or stretchers.

6. Offices/Working Areas

In our center, there are two offices, one for the director and the other one is shared with 4 people (coordinators, technicians, and research staff) located in the entrance corridor. Offices at the entrance reveal nice working area and maintain control by the

director and coordinators on what is happening in the center. As well as, the offices are located on the façade of the building with a nice view around. Each office is furnished with private desks for each employee and each desk contains a private computer (PC) for simulation preparations, administration, assessments etc. Offices also can be used for multiple uses. For instance, LCDs are placed in offices for offline observation through a live streaming system, where educators can assess learners from their offices, if no intervention is required.

It is important to have a simulation space that meets the conditions of both learning environment and working environment. Consider having private offices for simulation directors, coordinators, and technical staff in which a comfortable and a friendly working environment is provided.

7. Lobby Area

a. Reception Area

A reception area is of critical importance to make a first impression for the center. Consider having a reception area at the entrance with a receptionist in your simulation center for administrative purposes; to lead learners to the intended simulation room or lockers, provide schedule, and ensure sign ups, and for marketing purposes to communicate the center's business behaviors with prospective guests. Consider placing screen behind the reception for marketing presentations and the provided programs.

Initial greeting and directing in the center are crucial to decrease anxiety of learners, especially students attending simulation sessions for the first time. For example, initial presentation on simulation can be provided or learners can enter a cardiac arrest room to get them involved

.

b. Waiting Area

Including a waiting area in the lobby of the simulation center was considered for learners. Usually learners come before the simulation session and they need to have a waiting area that is comfortable, welcoming, and attractive.

c. Standardized Patient's (SPs) Area

in our center, there is no dedicated area for SPs; neither outside the lobby area or within the lobby. But the utility rooms (lockers and bathrooms) in the back seen area were considered for SPs. SPs will enter from the right bottom door, other than the main entrance, which is accessible to the back seen area; where they can create an actor's dressing space behind the seen and they can access lockers, bathrooms, or storage without meeting with learners.

We recommend having the SPs waiting or dressing area outside the main lobby, in order to avoid intersection with learners and incorrect pre-judgment of the scenario. Multiple entrance doors are recommended.

8. Utility Rooms

The AUBMC simulation center, the bathrooms with lockers cabinets for both genders (male and female) are located at the bottom right; and due to the pre-constructed foundations in the floor prior to simulation design planning they were not able to change the bathroom placements. Consider having lockers as many as the expected accommodation simultaneously in the center.

It is preferable to have additional bathrooms and lockers at the entrance or in the public area for learners or visitors, to avoid peeking on simulation preparations and interrupting others.

Additionally, learners get more involved once the real space and utilities are in place. Place sinks in the emergency room, NICU room, and utility room/storage room for medication preparations (e.g. syringes…). Additionally, it is important to remember the sink at the entrance of the OR (operating room), so the practitioners get more involved in the process as in reality.

a. <u>Isolated rooms:</u>

servers' room is one of the rooms to isolate from the simulation operation and the students, while it is accessible and near to technicians. In our center, the server room is at the top right of the center; this placement eliminates interference of students. Consider locating the servers' room in one of the corners of the center while it is very close to the

technician’s office; in case of any malfunction or breakdown he has easy and fast accessibility.

During the design, consider special treatment for the servers’ room; controlled access only for authorized technical staff because the equipment is very delicate, and great ventilation to avoid any failure or fire hazard due to the high temperature generated by servers (Kheirabadi and Groulx, 2016).

We have created a summary diagram of the organization of space for a simulation center, in which it includes all the necessary functions, sequence of rooms and flow of practitioner through simulation rooms. This diagram can be followed by another simulation facilities planning for a new learning and working space (as shown in Figure 6).

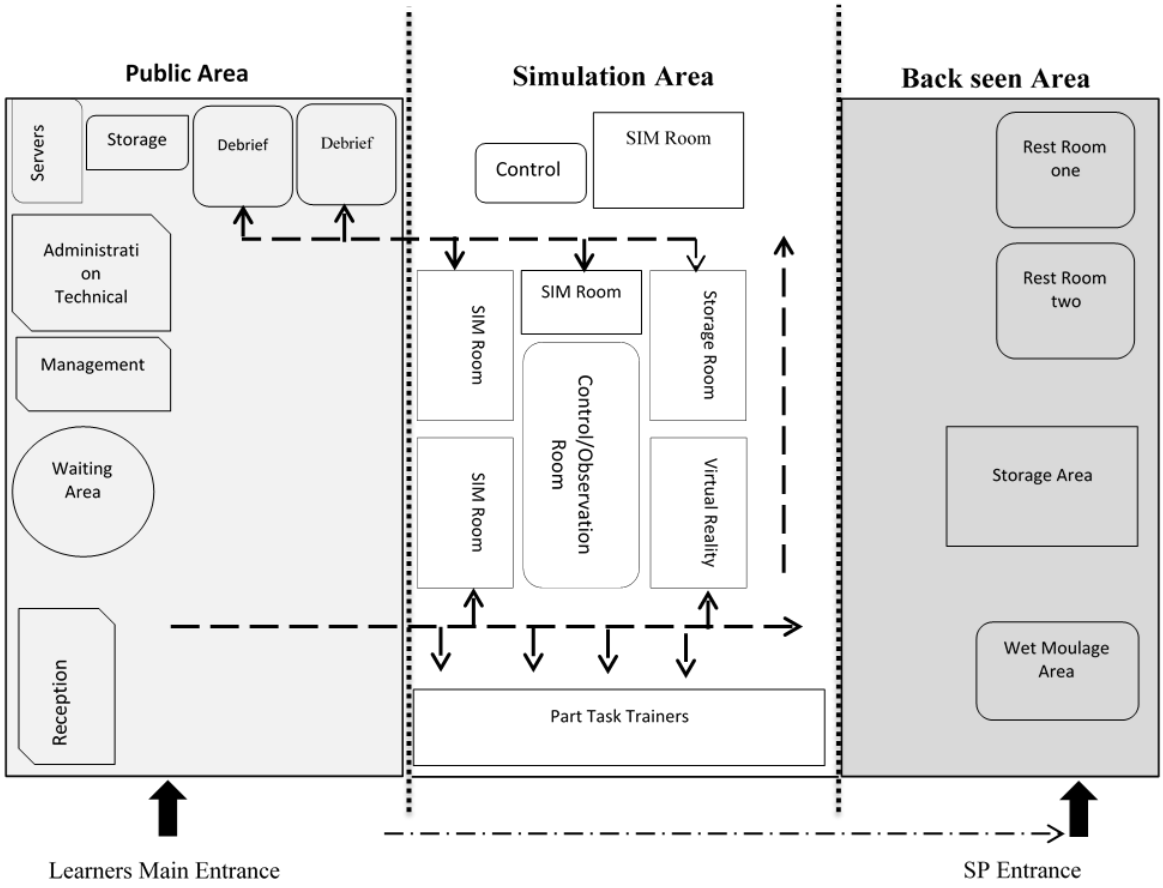


Figure 6 Organization of Space Diagram

D. Equipment

1. System and System Brand:

the simulation system or the simulator software is one of the initial considerations in the bidding and purchase phase. The system is usually purchased along with the patients' simulators. Important key aspects to consider in selecting the system and the equipment, in which the stakeholders at AUBMC simulation center followed: (1) build contract with privileged vendor; (2) seek optimal prices and meet the budget ; (3) seek high customer service and support such as maintenance needs and warranty.

The system must be durable and functional. Because it is probable to invest in various types of patients' simulators; ensure that the system effectively functions with any brand.

Invest in a system with live streaming capability; live streaming system facilitates flexibility. As discussed previously, instructors and faculty members can observe from their offices or from the debriefing rooms.

2. Simulators:

the choices of simulators highly depend on the simulation program the center is offering. Initially, list all disciplines and groups targeted, and identify the curriculum the center is adopting for an educational institution. Mostly, simulation centers utilize multidisciplinary groups, because this happens in the in-situ. Thus, ensure having patients' simulators that is adaptable to many disciplines, schools and uses.

One of the study participants mentioned that “you can purchase as many simulators as you want”. But before purchasing simulators consider the available space and the number of rooms in the center. Because mannequins are expensive; they are not supposed to be stored, in case of having space limitations. Select the simulators wisely and ensure optimizing the investment cost while meeting the program needs.

The Simulation Center at AUBMC provides simulation education for skills training and self-directed learning, multidisciplinary team simulation learning, and clinical practice. The center provides simulation learning in three simulation modalities, the following is a list of simulators utilized in the center:

a. Part-task Trainers

- For Nursing procedures as intravenous
- Intramuscular and intradermal injections
- Tracheostomy care and suctioning
- Urinary catheterization
- Wound care
- Heart and lung sounds
-

b. High-Fidelity Mannequins

the center contains 4 functional sim rooms, thus, we intended to have up to five HF mannequins:

- Pediatric Patient Simulator
- Birthing Simulator
- Adult Patient Simulator
- Adult HAL© for Nursing Care
- Nursing Patient Simulator
- **Mid-Fidelity mannequin** for OPG (Orthopantomogram)

c. Standardized Patients (SPs)

Trained SPs from various departments to act different scenarios in the simulation session.

3. Medical Equipment:

Medical simulation learning seeks improving learners' skills, experience, and transforming technical skills from simulation to real healthcare environment (Gaba, 2004). Thus, consider paying money for adding realism in the simulation center. Because the equipment and the interaction of human with such technological equipment is one of the contributors in medical errors (IOM report, 2000).

It is important to utilize full functional medical equipment in the simulation rooms. Real functional equipment immerses learners and students in the realism of the scenario because they are using similar medical equipment (e.g. monitors, ventilators, airways, defibrillators, suction machine, ultrasound etc.) as in the in-situ. Unfortunately, equipment

with low fidelity may increase learners' anxiety and confusion (Liu *et al., 2009*). Nonetheless, some centers could invest in malfunctioned real equipment instead of full-functional ones; because it's cheaper; but it works with specific scenarios not used for learning.

The placement of medical equipment in a simulation room should be placed like a real patient environment structure to avoid learners' waste of time and energy finding equipment and tools. The operating room is a good example, where all equipment and machines are fixed and structured as in real spaces.

4. Audiovisual Capacity:

at the AUBMC simulation center, each simulation room has two digital cameras located in either corners to capture wider viewing angle, and one optical camera located perpendicular to the bed (above the mannequin). Those cameras can be controlled (zoom in/out) to any intended view by the observer. The center utilizes mobile cameras in case of any shortage; or for a scenario happening in the corridor.

Additionally, each room has one speaker for announcements and one microphone. It is preferred to mount a ceiling flat microphone above the bed to reduce appearance. Consider investing in microphones other than the cameras' built in microphones, because they have low quality sound. One expert respondent stated that "The number of microphones needed depends on the room size; a room with more than 25 m^2 need more than one microphone."

Control rooms contain two personal computers (PC's) on each desk, one for controlling the mannequin simulator and one for personnel and annotation, and one microphone/headset for instructor's interference. In case of having clinics for standardized patients', consider buying laptops for students to ensure equal centralized services and information.

Simulation center design is not restricted to the layout and the structure of rooms, but audiovisual capacity should be considered and planned to ensure optimal communication and recording. Choose the audiovisual capacity (e.g. Number of cameras, microphones, and speakers) along with designing the layout and before the constructional phase, because pre-installation of power and data outlets and cables is required.

Recording and reviewing the simulation scenario is crucial for both controlling the scenario and debriefing the session that shows what really happened in the scenario. It is confusing on whether to mount cameras on ceiling, wall, or monitor etc. but it depends on the cameras' features the center is investing in and on the room size.

5. Maintenance Needs:

one of the key considerations for the medical equipment and the simulators is maintenance needs and cleaning. Simulators have to be maintained on weekly, monthly, or yearly bases, as well cleaned daily to avoid growing germs. Consider having a preventive maintenance schedule for the simulators and equipment to avoid sudden breakdowns. This task is usually done by the technical staff or the simulation coordinator on weekly or

monthly bases, but the simulators' vendor company is also responsible to provide preventive maintenance support annually or every 6 months.

E. Lighting

Lighting is an essential consideration in healthcare simulation center design. Studies show that it is important to have a balance between direct daylight and indirect light in healthcare spaces. Inefficient lighting affects the health of people working or learning in the space. Hence, natural light decreases stress and depression, improves vision, and increase performance (Brawley, 2009).

The AUBMC simulation center has a direct natural light from the façade of the building. The offices/working stations were located on side of the natural light source; where it is all glassed. Simulation rooms and offices have half glassed view to reflect daylight when needed and it can be closed with shades to avoid interruptions.

Consider adding windows on the building/center façade to reflect natural light to the working space. In our center, the lighting design was intended to reflect a friendly and aesthetic space for learning and working. A good lighting design attracts learners to feel more comfortable, as well the space reflects great reputation for the center.

F. Staffing Support

The AUBMC simulation center planned to hire four to five technical and non-technical employees. The center will utilize. The following is a list of required full- time staff in the center:

One director/manager: manage and oversee all administrative, data, finance, operational and reporting responsibilities of the simulation center for undergraduate and graduate program. Develop relationships faculty, coordinators, students and institution management to enhance the quality of education and learning.

One simulation coordinator: is in responsible of the learning environment to develop the program; prepare simulation scenarios, schedule the courses and simulation sessions, checkup the equipment and simulators, and make sure everything is going smoothly.

Two technicians from the IT (information technology) department/ BME (biomedical engineer): responsible of the continuous technical functionality in the center; such as: the preventive maintenance schedule for medical equipment and simulators, readily available for any potential breakdown or malfunction in the center, system upgrade and troubleshooting, and servers' and data functionality etc.

One researcher: handling research and potential studies in the medical simulation center and healthcare simulation learning generally.

Human resource/staffing is one of the main challenges in a simulation center. During the need's assessment phase at the AUBMC simulation lab we found a main

constraint; staffing shortage. Technical and non-technical support is a key aspect to consider in the initial phases of the design process; prior to zoning and planning the center's layout, because private working areas and offices with sufficient capacity should be included in the design.

The number of support personnel in the center depends on the number of simulation rooms, the number students accommodating the center, the program offered and the curriculum density, the number of simulators, and the budget available for funding the center. Practically, each three simulation rooms require one technical employee who has experience in medical equipment and specifically patient simulators and simulation system.

Additionally, non-technical staff is required to ensure smooth simulation operation and efficient learning and teaching environment. The number of simulation coordinators in the center depends on the program and the number of sessions offered simultaneously in the center. In our center, there will be prospectively four sessions running simultaneously; one simulation coordinator can prepare four simulation scenarios per day for different groups.

Both technical and non-technical staff needs simulation certification (e.g. Certified Healthcare Simulation Educator CHSE) and simulation training to understand how the patient simulator and the system work. Then, staff training program should be considered prior to opening the center. It was considered in the phase of bidding and purchase of the project where consultants offer simulation training program as part of the contract.

At the AUBMC simulation center there was four types of industry training program on the use of system, AV system, and simulators:

- Seminars: 3 to 4 full days on software and hardware.
- Training for life-long-term (web-based training as recorded trainings).
- Custom made training: training sessions in Germany or the US.
- Webinars and Team in Hungry for the team that takes care of the software- the person must be allocated to keep up with continuous troubleshooting and team development.

G. Limitations

This study has some limitations. First, it was a case study in Lebanon; there was a limited number of labs and centers in the region to study their design perspectives and experience and it may or may not be generalizable to all simulation centers in the region or abroad. Secondly, there was a recall bias because the recruited participants weren't interviewed directly during the design and planning phase, but they were interviewed after the design was finalized. Lastly, the project was behind schedule and we didn't have the chance to see things in practice; in order to include in the discussions on how the operation works efficiently.

CHAPTER VI

CONCLUSION

Planning, designing, and structuring a simulation center is a long complex process based on the AUBMC experience. One of the study objectives, was to find an optimal design for the AUBMC simulation center. But based on results and findings we concluded that there is no one optimal or ideal space layout and design for a simulation center, there is "no one size/style fits all". Each simulation center structure and function adapt to the program needs and the project's goals. There is no need to have a huge simulation center while no high capacity needed, or high-density program offered. Through the AUBMC experience, stakeholders faced some constructional and space constraints, but they adapted to such constraints while meeting the institution's needs and vision. Thus, the design team came up with an ideal space that meets the center's needs; and to reflect a great ten years of experience in simulation.

There is no standard layout or design to build a simulation center, but there is an evidence of experience and practice. The operation of simulation should be very well understood in order to design an efficient simulation space. The provided guidelines help produce an efficient simulation center/lab. These guidelines decrease the confusion of anyone planning to construct a simulation center or lab, because it provides a detailed structure of the process; who to involve, what important functions to include in the design, how to think about the flow and layout, what challenges the planner will face, how to

consider every user and utilize each equipment in the center, and what architectural design mistakes to avoid while minimizing the costs and optimizing the space. Once things come to practice everything change; thus, during the design, ensure a flexible and a multi-purpose space.

APPENDIX I

AUBMC SIMULATION CENTER LAYOUT AND DESIGN

APPENDIX II

CONSENT FORM

Developing design strategy for an optimal simulation center at AUBMC
The AUBMC experience
Dr. Selim Hani (PI), Carla Dleikan (Co-I)

Consent Form for Interview

I am Carla Dleikan, a graduate student conducting my Master's studies in the "Maroun Semmaan Faculty of Engineering and Architecture" at the American University of Beirut in the Engineering Management Program. As for my thesis, I am conducting a research study about developing design strategy for an optimal medical simulation center at the "American University of Beirut Medical Center". The interview will provide the gathering data that would help understand the challenges and obstacles regarding the space and layout in the "in-situ simulation" at the "Emergency Department". As well, getting deeper insight about the recommendations and expectations for the new design of the medical simulation center that will provide an efficient learning environment. This data would help recognize the key considerations for an optimal design. This will be used in academic presentations as well in published research.

You were recruited for this study through email. A total of 10 people will be recruited to participate in this interview.

Before you participate, I would like you to approve and be attentive of the following:

- You have experience in medical simulation.
- You are literate in English.
- You are aware that this participation will require 40 to 60 minutes.
- You are aware that your participation is totally anonymous, and researchers will not be disclosed any information about your identity.
- You are allowed to skip any question at any time for any reason, and this will not affect the validity of your participation.

- You are aware that this interview is not tape recorded.
- You will not be subjected to any risk and embarrassment associated with participation in this interview that is greater than ordinarily encountered in daily life.
- You are aware that the data collected will be stored on a password secured laptop. Only the principal investigator and the co-investigator will have access to the data. The data will be kept for 10 years and then destroyed.
- Data will be published as aggregate.
- You are aware that your participation is voluntary and if you wish to not participate or withdrawal from the study, there will be no loss of benefits to which you are otherwise entitled nor will it affect your relationship with AUB or AUBMC.

If you have any question about your right as a participant or any complaints about the study, you can contact the IRB office at AUB: Gefinor block B 5th floor, phone number 01-35000, extension 5445.

If you have inquiries about this research subject or your participation, please feel free to email me at ctd02@mail.aub.edu

Do you agree to the above terms? By signing below, you consent that you have read the terms above.

Researcher's Name: _____ Participant's Name: _____

Researcher's signature: _____ Participant's signature: _____

Date: _____ Date: _____

APPENDIX III

INTEVIEW QUESTIONAIRE

Developing Design Strategy for an Optimal Simulation Center-based Programme: The AUBMC Experience

Selim Hani, PhD (PI), Dr.s Rana Sharara-Chami, MD, FAAP (Co-I),
Zavi Lakissian, MD, MPH (Co-I), Carla Dleikan, MSc (Candidate) (Co-I)

Interview Guide

Data to be collected prior to the interview

Phone
E-mail
Date
Start Time
End Time

Demographic Information of the interviewee

1. Age:
   ___ 40-45
   ___ 46-50
   ___ 51-54
   ___ 55 or above

2. Gender:
   ___ Female
   ___ Male

3. Role in simulation (Biomedical Engineer, Sim-Tech, simulation specialist, Simulation educator, operations manager, director, etc.):
   _____

4. Primary education (nursing, lab sciences, etc.): _____

5. Experience in simulation:

   i. Years of working experience:
      ___ Under 5
      ___ 5-8
      ___ 8 or above

   ii. Years of experience in medical simulation
      ___ Under 2
      ___ 2-5
      ___ 5 or above

6. Simulation Certifications (like Certified Healthcare Simulation Educator "CHSE" from SSH)
   ___ Yes
   ___ No
   ___ Other (e.g. Harvard CMS, Boston/Bristol masterclass etc.)

Current Environment:
8. How would you describe your current simulation facility?

Prompts:
Is it a:
___ Simulation Center
___ Lab
___ Allocated clinical patient room for Simulation 'in situ'
Do you have satellite centers (equipment or skills labs at multiple hospitals)?
___ Yes
___ No
Please specify?
Are you affiliated with an academic institution?
___ Yes
___ No
Is the facility accredited? (If no, Why?)
___ National League for Nursing Accreditation Commission (NLNAC)
___ American Association of Colleges of Nursing (AACN)
___ Joint Commission on Accreditation of Healthcare Organizations (JACHO)
___ Society for Simulation in Healthcare (SSH)
___ Other _____
Do you conduct in-situ and mobile simulations?
___ Yes
___ No

9. Question: How would you describe the facility's current configuration / flow (Structurally)?

Prompts:
What is the square footage of the current Configuration (Sim suites, seminar room, standardized patient areas etc.)
Does the facility have natural light?
How many windows per room does it have?
Are there windows in all / some rooms of the facility? Especially the teaching rooms?
How many rooms does it contain?
What is the function of these rooms?
Describe the audiovisual technology of the lab? *(Bee Line/ Gaumard, CAE, Laerdal? How and why was it chosen?*
Is each room equipped with Audio video cameras with a live stream/capture to a common observation room? Does each room have a separate 'control room'? *Where are the cameras placed?*
How many debriefing / tutorial rooms does the facility have?
How many storage rooms do you have? For manikins?
Is it adequate? What is stored in the storage rooms? Do you have a locked and secure storage for medications--- if real ones are used during simulation? Who is responsible for these medications?
What about a costume wardrobe*? Where are they stored?* Do you have designated area for wet moulage and inventor space (similar to Boston's 3D printing work area)?
Does the lab have a reception area?
Where is it located?
What purpose does it serve (e.g. registration, course material distribution, bookings, etc.)? For whom?
Where are the bathrooms located? Are the sinks accessible?
How is the equipment maintained?
Are you supported by a preventive maintenance program/schedule? (if yes, Who performs the industry preventative maintenance?)

Studies have shown that harmful microorganisms can grow on manikins following in-situ activities, are these safety concerns taken into account?

Resources: Personnel and Equipment

10. How many dedicated staff work at the Centre / lab? *In what capacity, roles?*
11. *Does staff have their own designated spaces? Desks? Offices? Does the Biomedical Engineer stay full time at the lab? if so, do they have their own 'office'?*

    Is staffing adequate for the program's /Centre's needs?

    ___ Yes
    ___ No

12. How many BME, ME, or IE technicians do you need? And are they readily available for the sim lab?

13. What equipment do you have? How many/ type manikins, part task trainers, virtual reality? How many beds? *Do you have designated areas for clinical skills teaching? SP program?* If simulated medications are used, what simulated medication program do you have?

Learning and Education offering

14. What types of disciplines, professionals or programs use the current facility?
    ___ Nursing
    ___ Medicine
    ___ Allied Health
    ___ EMS
    Other _____

15. How is the simulation center/lab currently being used?

    ___ Classroom
    ___ Skills proficiency
    ___ Self-directed simulation learning
    ___ Team simulation learning
    ___ Clinical practice

16. Do you perform OSCEs or assessments in the simulation lab?

    ___ Yes
    ___ No
    Is the current set up conducive for these purposes?

17. Is the lab accessible to students and / or medical professionals in the institution? Participants from other facilities?
18. Is it open for study outside lab hours? Or only for designated classes? Is there a possibility for outsiders to use the lab for teaching activities, conferences, seminars, workshops? Certifications?

For existing simulation centers/lab

19. Does the lab have a source of Revenue and a strategic business model?
20. What are some of the current challenges?

21. If you could design your ideal space what would it look like?
22. Is the new center/lab living up to the expectations? How are you measuring outcomes on return on investment?
23. Are you affiliated with a Quality and Safety program e.g. discussions RCAs? *(if yes, how?)*
24. In retrospect would you do things differently in the design and layout? Are there mistakes /challenges? Errors?
25. Prior to undertaking the renovation, did you do needs assessment or was there a research step prior to the renovation?

    ___ Yes
    ___ No

26. What feedback do users have for the current design? Architects, facilities management?

For institutions undertaking a new build or renovation

27. What are the significant challenges of implementing simulation modalities within your facility within specific curricula curriculum?
    ___ Space
    ___ Funding
    ___ Faculty
    ___ Curriculum integration
    ___ Equipment
    ___ Human Resources
    ___ Other (_____)

28. What are your expectations and recommendations for the new simulation center? [*If not mentioned, can ask about, the expected changes in the design and the flow? How it will impact the curriculum?]*

29. What are your concerns regarding the design and layout of the new simulation center?
30. Can we contact you later for further questions?

BIBLIOGRAPHY

Abatzis, V. T., & Littlewood, K. E. (2015). Debriefing in simulation and beyond. International anesthesiology clinics, 53(4), 151-162.

Abrahamson, S., Cowen, A. E., Denson, J. S., McGeary, H. M., Campbell, C. B., & Wolf, R. M. (1972;2004;). Effectiveness of a simulator in training anesthesiology residents. Gut, 13(5), 395. doi:10.1136/qhc.13.5.395;10.1136/gut.13.5.395;

Abrahamson, S., Denson, J. S., & Wolf, R. M. (1969). Effectiveness of a simulator in training anesthesiology residents. *Academic Medicine*, *44*(6), 515-9.

Almutary, H. H., & Lewis, P. A. (2012). Nurses' willingness to report medication administration errors in Saudi Arabia. *Quality Management in Healthcare*, *21*(3), 119-126.

Arzi, H. J. (1998). Enhancing science education through laboratory environments: More than walls, benches and widgets. International handbook of science education, 595-608.

Barrett, P., & Baldry, D. (2009). Facilities management: Towards best practice. John Wiley & Sons.

Barry Issenberg, S., Mcgaghie, W. C., Petrusa, E. R., Lee Gordon, D., & Scalese, R. J. (2005). Features and uses of high-fidelity medical simulations that lead to effective learning: a BEME systematic review. *Medical teacher*, *27*(1), 10-28.

Bayazidi, S., Zarezadeh, Y., Zamanzadeh, V., & Parvan, K. (2012). Medication error reporting rate and its barriers and facilitators among nurses. Journal of Caring Sciences, 1(4), 231.

Becker, F., & Parsons, K. S. (2007). Hospital facilities and the role of evidence-based design. Journal of Facilities Management, 5(4), 263-274.

Bergin, R. A., & Fors, U. G. (2003). Interactive simulated patient—an advanced tool for student-activated learning in medicine and healthcare. *Computers & education*, *40*(4), 361-376.

Bhagwat, M. (2012). Simulation and anaesthesia. *Indian journal of Anaesthesia*, *56*(1), 14.

Billings, C. E., & Reynard, W. D. (1984). Human factors in aircraft incidents: results of a 7-year study. Aviation, Space, and Environmental Medicine, 55(10), 960-965.

Bond, W. F., Spillane, L., & CORD Core Competencies Simulation Group. (2002). The use of simulation for emergency medicine resident assessment. *Academic Emergency Medicine*, *9*(11), 1295-1299.

Boulet, J. R., & Murray, D. J. (2010). Simulation-based assessment in anesthesiology: Requirements for practical implementation. *Anesthesiology*, *112*(4), 1041-1052. doi:10.1097/ALN.0b013e3181cea265

Brach, C., & Fraserirector, I. Agency for Healthcare Research and Quality, (2000). *Can Cultural Competency Reduce Racial And Ethnic Health Disparities*?

Brawley, E. C. (2009). Enriching lighting design. Neuro Rehabilitation, 25(3), 189-199.

Brownlee, S. (2007). Overtreated: Why too much medicine is making us sicker and poorer. United States:

Bullough, A. S., Wagner, S., Boland, T., Waters, T. P., Kim, K., & Adams, W. (2016). Obstetric team simulation program challenges. Journal of clinical anesthesia, 35, 564-570.

Calhoun, A. W., Boone, M. C., Peterson, E. B., Boland, K. A., & Montgomery, V. L. (2011). Integrated in-situ simulation using redirected faculty educational time to minimize costs: a feasibility study. Simulation in Healthcare, 6(6), 337-344.

Carayon, P., Wetterneck, T. B., Hundt, A. S., Ozkaynak, M., DeSilvey, J., Ludwig, B., ... & Rough, S. S. (2007). Evaluation of nurse interaction with bar code medication administration technology in the work environment. Journal of Patient Safety, 3(1), 34-42.

Chaudhury, H., Mahmood, A., & Valente, M. (2009). The effect of environmental design on reducing nursing errors and increasing efficiency in acute care settings: a review and analysis of the literature. Environment and Behavior, 41(6), 755-786.

Classen, D. C., Resar, R., Griffin, F., Federico, F., Frankel, T., Kimmel, N., ... & James, B. C. (2011). 'Global trigger tool'shows that adverse events in hospitals may be ten times greater than previously measured. *Health affairs*, *30*(4), 581-589.

Cooper, J. B., & Taqueti, V. (2004). A brief history of the development of mannequin simulators for clinical education and training. BMJ Quality & Safety, 13(suppl 1), i11-i18.

Couto, T. B., Kerrey, B. T., Taylor, R. G., FitzGerald, M., & Geis, G. L. (2015). Teamwork skills in actual, in situ, and in-center pediatric emergencies: performance levels across settings and perceptions of comparative educational impact. Simulation in Healthcare, 10(2), 76-84.

Dillard, A. E. (2002). Validation of advanced flight simulators for human-factors operational evaluation and training programs. Foundations, 2, V7V.

Dovey, K., & Fisher, K. (2014). Designing for adaptation: The school as socio-spatial assemblage. The Journal of Architecture, 19(1), 43-63.

Eagle, D. M., Coltvet, G., & Farley, D. (2010). The Mayo Clinic, multidisciplinary simulation center. Journal of surgical education, 67(6), 470-472.

Emanuel, L., Berwick, D., Conway, J., Combes, J., Hatlie, M., Leape, L., ... & Walton, M. (2008). What exactly is patient safety?. In Advances in patient safety: new directions and alternative approaches (Vol. 1: Assessment). Agency for Healthcare Research and Quality.

Flanagan, B., Nestel, D., & Joseph, M. (2004). Crisis resource management Making patient safety the focus: Crisis Resource Management in the undergraduate curriculum. *Medical Education*, *38*(1), 56–66.

Fukui, Y., & Smith, N. T. (1981). Interactions among ventilation, the circulation, and the uptake and distribution of halothane--use of a hybrid computer multiple model: I. The basic model. *Anesthesiology*, *54*(2), 107-118.

Gaba, D. M. (2004). The future vision of simulation in health care. Quality and Safety in Health Care, 13(suppl 1), i2-i10. doi:10.1136/qshc.2004.009878

Gaba, D. M., & DeAnda, A. (1988). A comprehensive anesthesia simulation environment: re-creating the operating room for research and training. Anesthesiology, 69(3), 387-394.

Good, M. L. (2003). Patient simulation for training basic and advanced clinical skills. Medical education, 37, 14-21.

Grenvik, A., & Schaefer, J. (2004). From Resusci-Anne to Sim-Man: the evolution of simulators in medicine. Critical care medicine, 32(2), S56-S57.

Halamek, L. P., Kaegi, D. M., Gaba, D. M., Sowb, Y. A., Smith, B. C., Smith, B. E., & Howard, S. K. (2000). Time for a new paradigm in pediatric medical education: teaching neonatal resuscitation in a simulated delivery room environment. Pediatrics, 106(4), e45-e45.

Heitor, T. V., & da Silva, J. M. F. (2009). Portugal's Secondary School Modernisation Programme.

Henriksen, K., Isaacson, S., Sadler, B. L., & Zimring, C. M. (2007). The role of the physical environment in crossing the quality chasm. The Joint Commission Journal on Quality and Patient Safety, 33(11), 68-80.

Higgins, S., Hall, E., Wall, K., Woolner, P., & McCaughey, C. (2005). The impact of school environments: A literature review. London: Design Council.

Issenberg, S. B., & Scalese, R. J. (2007). Best evidence on high-fidelity simulation: what clinical teachers need to know. *The Clinical Teacher*, *4*(2), 73-77.

Issenberg, S. B., McGaghie, W. C., Hart, I. R., Mayer, J. W., Felner, J. M., Petrusa, E. R., ... & Gordon, D. L. (1999). Simulation technology for health care professional skills training and assessment. *Jama*, *282*(9), 861-866.

James, J. T. (2013). A new, evidence-based estimate of patient harms associated with hospital care. Journal of patient safety, 9(3), 122-128.

Jeffries, P. R. (2005). A framework for designing, implementing, and evaluating: Simulations used as teaching strategies in nursing. *Nursing education perspectives*, *26*(2), 96-103.

Kallio, T. J., Kallio, K. M., & Blomberg, A. J. (2015). Physical space, culture and organisational creativity–a longitudinal study. Facilities, 33(5/6), 389-411.

Kallio, T. J., Kallio, K. M., & Blomberg, A. J. (2015). Physical space, culture and organisational creativity–a longitudinal study. Facilities, 33(5/6), 389-411.

Kheirabadi, A. C., & Groulx, D. (2016). Cooling of server electronics: A design review of existing technology. Applied Thermal Engineering, 105, 622-638.

Kobayashi, L., Parchuri, R., Gardiner, F. G., Paolucci, G. A., Tomaselli, N. M., Al-Rasheed, R. S., ... & Goldlust, E. (2013). Use of in situ simulation and human factors engineering to assess and improve emergency department clinical systems for timely telemetry-based detection of life-threatening arrhythmias. BMJ Qual Saf, 22(1), 72-83.

Kochevar, D. T. (2004). The critical role of outcomes assessment in veterinary medical accreditation. Journal of veterinary medical education, 31(2), 116-119.

Kohn, L. T., Corrigan, J. M., & Donaldson, M. S. (2000). To err is human: Building a safer health system. Washington, D.C: National Academy Press.

Kohn, L. T., Corrigan, J., & Donaldson, M. S. (2000). To err is human: building a safer health system (Vol. 6). Washington, DC: National academy press.

Kondro, W. (2004). Canadian report quantifies cost of medical errors. *The Lancet*, *363*(9426), 2059.

Konge, L., & Lonn, L. (2016). Simulation-based training of surgical skills. Perspectives on medical education, 5(1), 3-4.

Kurrek, M. M., & Devitt, J. H. (1997). The cost for construction and operation of a simulation centre. *Canadian Journal of anesthesia*, *44*(11), 1191.

Kutzin, J. M. (2016). Simulation Design Considerations 2.0: optimizing space and operations. Clinical Simulation in Nursing, 12(6), 187-196.

Lamb, G., Zimring, C., Chuzi, J., & Dutcher, D. (2010). Designing better healthcare environments: Interprofessional competencies in healthcare design. Journal of Interprofessional Care, 24(4), 422-435. doi:10.3109/13561820903520344

Lazzara, E. H., Benishek, L. E., Dietz, A. S., Salas, E., & Adriansen, D. J. (2014). Eight critical factors in creating and implementing a successful simulation program. The Joint Commission Journal on Quality and Patient Safety, 40(1), 21-29.

Leape, L. L. (2002). Reporting of adverse events. The New England journal of medicine, 347(20), 1633.

Lederman, R., Dreyfus, S., Matchan, J., Knott, J. C., & Milton, S. K. (2013). Electronic error-reporting systems: A case study into the impact on nurse reporting of medical errors. *Nursing outlook*, *61*(6), 417-426.

Liu, D., Macchiarella, N. D., & Vincenzi, D. A. (2009). Simulation fidelity. Human factors in simulation and training, 61-73.

Mahony, P., Hextall, I., & Richardson, M. (2011). 'building schools for the future': Reflections on a new social architecture. Journal of Education Policy, 26(3), 341-360. doi:10.1080/02680939.2010.513741

Maran, N. J., & Glavin, R. J. (2003). Low-to high-fidelity simulation–a continuum of medical education?. Medical education, 37, 22-28.

Miller, K., Kowalski, R., Arnold, R., Coffey-Zern, S., & Monson, S. (2016, June). Designing Health Care Facilities to Maximize Productivity and Patient Outcomes. In Proceedings of the International Symposium on Human Factors and Ergonomics in Health Care (Vol. 5, No. 1, pp. 38-43). Sage India: New Delhi, India: SAGE Publications.

Møller, T. P., Østergaard, D., & Lippert, A. (2012). Facts and fiction – training in centres or in situ. Trends in Anaesthesia and Critical Care, 2(4), 174-179. doi:10.1016/j.tacc.2012.03.006

Motola, I., Devine, L. A., Chung, H. S., Sullivan, J. E., & Issenberg, S. B. (2013). Simulation in healthcare education: a best evidence practical guide. AMEE Guide No. 82. *Medical Teacher*, *35*(10), e1511-e1530.

Murphy, J. I. (2013). Using plan do study act to transform a simulation center. Clinical simulation in Nursing, 9(7), e257-e264.

Nehring, W. M. (2008). U.S. boards of nursing and the use of high-fidelity patient simulators in nursing education. *Journal of Professional Nursing*, *24*(2), 109-117. doi:10.1016/j.profnurs.2007.06.027

Okuda, Y., Bryson, E. O., DeMaria Jr, S., Jacobson, L., Quinones, J., Shen, B., & Levine, A. I. (2009). The utility of simulation in medical education: what is the evidence?. Mount Sinai Journal of Medicine: A Journal of Translational and Personalized Medicine: A Journal of Translational and Personalized Medicine, 76(4), 330-343

Palaganas, J. C., Epps, C., & Raemer, D. B. (2014). A history of simulation-enhanced interprofessional education. Journal of interprofessional care, 28(2), 110-115.

Patterson, M. D., Geis, G. L., Falcone, R. A., LeMaster, T., & Wears, R. L. (2013). In situ simulation: detection of safety threats and teamwork training in a high risk emergency department. BMJ Qual Saf, 22(6), 468-477.

Pemsel, S., Widén, K., & Hansson, B. (2010). Managing the needs of end-users in the design and delivery of construction projects. Facilities, 28(1/2), 17-30.

Perkins, G. D. (2007). Simulation in resuscitation training. *Resuscitation*, *73*(2), 202-211.

Philip, J. H. (1986). Gas Man®—An example of goal oriented computer-assisted teaching which results in learning. *International journal of clinical monitoring and computing*, *3*(3), 165-173.

Ramanathan, R., Leavell, P., Wolfe, L. G., & Duane, T. M. (2014). Agency for healthcare research and quality patient safety indicators and mortality in surgical patients. *The American Surgeon*, *80*(8), 801.

Rauen, C. A. (2004). Simulation as a teaching strategy for nursing education and orientation in cardiac surgery. Critical care nurse, 24(3), 46-51.

Reason, J. (1990). *Human error*. Cambridge university press.

Rehrig, S. T., Powers, K., & Jones, D. B. (2008). Integrating simulation in surgery as a teaching tool and credentialing standard. *Journal of Gastrointestinal Surgery*, *12*(2), 222-233. doi:10.1007/s11605-007-0250-8

Reiling, J., Hughes, R. G., & Murphy, M. R. (2008). The impact of facility design on patient safety. In Patient safety and quality: An evidence-based handbook for nurses. Agency for Healthcare Research and Quality (US).

Riley, W., Davis, S., Miller, K. M., Hansen, H., & Sweet, R. M. (2010). Detecting breaches in defensive barriers using in situ simulation for obstetric emergencies. *BMJ Quality & Safety*, *19*(Suppl 3), i53-i56.

Rosen, K. R. (2008). The history of medical simulation. *Journal of critical care*, *23*(2), 157-166.

Rosen, M. A., Hunt, E. A., Pronovost, P. J., Federowicz, M. A., & Weaver, S. J. (2012). In situ simulation in continuing education for the health care professions: a systematic review. *Journal of Continuing Education in the Health Professions*, *32*(4), 243-254.

Rothgeb, M. K. (2008). Creating a nursing simulation laboratory: A literature review. Journal of Nursing Education, 47(11), 489-494.

Roux, L., Pratt, M., Tengs, T. O., Yore, M. M., Yanagawa, T. L., Van Den Bos, J., ... & Kohl III, H. W. (2008). Cost effectiveness of community-based physical activity interventions. *American journal of preventive medicine*, *35*(6), 578-588.

Savoldelli, G. L., Naik, V. N., Hamstra, S. J., & Morgan, P. J. (2005). Barriers to use of simulation-based education. Canadian Journal of Anesthesia, 52(9), 944-950.

Scalese, R. J., Obeso, V. T., & Issenberg, S. B. (2008). Simulation technology for skills training and competency assessment in medical education. Journal of general internal medicine, 23(1), 46-49.

Scott, D. E. (2006). Designing better physical environments for today's nurses. The Oklahoma nurse, 51(4), 21.

Seropian, M. A., Alinier, G., Hssain, I., Driggers, B. J., Brost, B. C., Dongilli, T. A., & Lauber, M. C. (2014). Building a simulation center: Key design strategies and considerations. In defining excellence in simulation programs. Wolters Kluwer Health Adis (ESP).

Seropian, M., & Lavey, R. (2010). Design considerations for healthcare simulation facilities. Simulation in Healthcare, 5(6), 338-345.

Shappell, S., Detwiler, C., Holcomb, K., Hackworth, C., Boquet, A., & Wiegmann, D. A. (2017). Human error and commercial aviation accidents: an analysis using the human factors analysis and classification system. In *Human Error in Aviation* (pp. 73-88). Routledge.

Sharek, P. J., Parry, G., Goldmann, D., Bones, K., Hackbarth, A., Resar, R., . . . Landrigan, C. P. (2011). Performance characteristics of a methodology to quantify adverse events over time in hospitalized patients. *Health Services Research*, *46*(2), 654-678. doi:10.1111/j.1475-6773.2010.01156.x

Smith, T. J. (2013). Designing learning environments to promote student learning: Ergonomics in all but name. Work, 44(Supplement 1), 39-60.

Sorensen, J. L., Ostergaard, D., Leblanc, V., Ottesen, B., Konge, L., Dieckmann, P., & Vleuten, C. v. d. (2017). Design of simulation-based medical education and advantages and disadvantages of in situ simulation versus off-site simulation. BMC Medical Education, 17(1), 20. doi:10.1186/s12909-016-0838-3

Sørensen, J. L., Van der Vleuten, C., Lindschou, J., Gluud, C., Østergaard, D., LeBlanc, V., ... & Kjærgaard, H. (2013). 'In situ simulation'versus' off site simulation'in obstetric emergencies and their effect on knowledge, safety attitudes, team performance, stress, and motivation: study protocol for a randomized controlled trial. Trials, 14(1), 220.

Steinke, C., Webster, L., & Fontaine, M. (2010). Evaluating building performance in healthcare facilities: An organizational perspective. HERD: Health Environments Research & Design Journal, 3(2), 63-83. doi:10.1177/193758671000300207

Strachan, I. W. (2000). Technology leaps all around propel advances in simulators. National Defense, 85(564), 86.

Stryker, J. B., Santoro, M. D., & Farris, G. F. (2012). Creating collaboration opportunity: designing the physical workplace to promote high-tech team communication. IEEE transactions on engineering management, 59(4), 609-620.

Takashina, T., Masuzawa, T., & Fukui, Y. (1990). A new cardiac auscultation simulator. *Clinical Cardiology*, *13*(12), 869.

Taylor, A. (2009). Linking architecture and education: Sustainable design for learning environments. UNM Press.

Thompson, T. L., & Bonnel, W. B. (2008). Integration of high-fidelity patient simulation in an undergraduate pharmacology course. *Journal of Nursing Education*, *47*(11), 518-521.

Tumulty, G., Jernigan, I. E., & Kohut, G. F. (1994). The impact of perceived work environment on job satisfaction of hospital staff nurses. Applied Nursing Research, 7(2), 84-90.

Tuoriniemi, P., & Schott-Baer, D. (2008). Implementing a high-fidelity simulation program in a community college setting. *Nursing Education Perspectives*, *29*(2), 105-109.

United States. Agency for Healthcare Research and Quality. (2001). Quality research for quality health care: A report from AHRQ on recent activities and future directions. United States:

Van Den Bos, J., Rustagi, K., Gray, T., Halford, M., Ziemkiewicz, E., & Shreve, J. (2011). The $17.1 billion problem: the annual cost of measurable medical errors. *Health Affairs*, *30*(4), 596-603.

Wang, E. E. (2011). Simulation and adult learning. *Disease-a-month*, *57*(11), 664-678.

Watterson, L., Flanagan, B., Donovan, B., & Robinson, B. (2000). Anaesthetic simulators: training for the broader health-care profession. Australian and New Zealand Journal of Surgery, 70(10), 735-737.

Williams, N. N., Mittal, M. K., Dumon, K. R., Matika, G., Pray, L. A., Resnick, A. S., & Morris, J. B. (2011). Penn medicine clinical simulation center. Journal of surgical education, 1(68), 83-86.

Zigmont, J. J., Kappus, L. J., & Sudikoff, S. N. (2011, April). The 3D model of debriefing: defusing, discovering, and deepening. In *Seminars in perinatology* (Vol. 35, No. 2, pp. 52-58). WB Saunders.

Ziv, A., Wolpe, P. R., Small, S. D., & Glick, S. (2003). Simulation-based medical education: an ethical imperative. Academic medicine, 78(8), 783-788.

Ziv, Stephen D. Small, Paul Root Wolpe, Amitai. (2000). Patient safety and simulation-based medical education. Medical Teacher, 22(5), 489-495.