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An International Summer Biomedical Research Program for Undergraduate Medical Students

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Abstract

Purpose: The declining physician-scientist number is alarming. Therefore, this study is designed to establish early exposure to undergraduate research interest in science careers and generates physician-scientist workforces.

Materials and methods: In this paper, we report the experience and student's perceptions of an innovative summer research program and examine how it could influence students' interest in research careers.

Results: During the summer of 2012, fourteen undergraduate medical students from Alfaisal University, Riyadh, Saudi Arabia, attended a month-long summer biomedical research program at Texas A&M Health Science Center College of Medicine in Temple, Texas, USA. The program was designed to expose students to four domains: 1) an intensive basic science research experience, 2) extraordinary aspects of clinical medicine, 3) collaborative research projects, and 4) social entertaining activities. At the end of the program, a self-administered questionnaire was used to explore participants' experiences and evaluate the program. Majority of students reported various research skills and knowledge gains, personal and professional gains, negative insights about research and clarifications of a research career. Moreover, majority were satisfied with the overall summer program and recommended it to others.

Conclusion: Participation in such scholarly programs enhances research intellectual and practical skills, supports participation in future research activities and increases interest to pursue physician-scientist careers.

Keywords: Medical students; Physician-scientist; Summer program; Translational medical research; Undergraduate research

Abbreviations: NIH: National Institute of Health; NSF: National Science Foundation; TAMHSC-COM: Texas A&M Health Science Center-College of Medicine

Introduction

Translational research is a significant and rapidly growing aspect of the scientific research enterprise. Transitional research integrates innovations in biomedical and clinical sciences, and translates these findings from the bench to useful and clinically applicable bedside clinical practices [1,2]. In a sense, translational research is a paradigm integrating the separated disciplines of basic science and applied clinical research. Physician-scientists are essential key players in translational research teams. Physician-scientists are defined as individuals holding medical training degrees (MD or MD/PhD) and carrying out biomedical research activities (basic science, patient-oriented or disease-oriented) as their primary professional careers [3]. Physicians-scientists, with one foot in medical clinical practice, and one foot in biomedical research, they are distinctively oriented to promote bench-to-bedside scientific research enterprise, accelerate innovative discovery, enhance medical education, advance medical and clinical sciences, augment evidence-based practice, and ultimately improve patient healthcare diagnostics and therapeutics [4].

Despite the importance of translational research enterprise and advances in biomedical and clinical research ventures, the number of physician-scientist workforce has not kept pace. Over the past three decades, the number of physician-scientists has dropped markedly. At present, only minority of prospective medical students chooses academic medicine or physician-scientist as a professional career [3,5-9]. This is of a challenge for young female undergraduate medical students who are greatly underrepresented in this area [7,10,11]. Moreover, physicians with comprehensive knowledge, vast experience and official training in research design, execution, methodology, data interpretation and statistical analysis are becoming a scarce species. Nowadays, physician-scientists are described as "endangered and essential species" [9]. Physician-scientists are essential players in advancing the science of medicine through biomedical, clinical, and translational research. The existence of few physician-scientists to play this vital role is a serious matter. It has been speculated that if this declining trend keeps going on in this manner the future of advancing sciences will come to a catastrophic end [12]. Reasons for this rapidly declining trend and possible measures to reverse it have been discussed extensively in literature [3,7,12-19].

One mechanism to be re-emphasized in this paper is early exposure to research during undergraduate medical education. Early exposure

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to undergraduate research has been recognized as a successful mechanism to promote interest in science research careers and generate physician-scientist workforces [13,15,17,20,21]. Former supporters of undergraduate research have witnessed their commendations fostered after the publication of Boyer's Commission Report. The report has dramatically reformed how universities should approach undergraduate education. In specific, it was advocated that research-based learning should be the standard for any given undergraduate education. Moreover, it was urged to implement a dedicated inquiry-based freshman year at an early stage of undergraduate education. Since then, integration of teaching and research in undergraduate medical curricula has been greatly emphasized and employed in Western countries [17,18,20,22]. However, integration of teaching into an ongoing process of inquiry-based learning has not been sufficiently put into practice in most of the Middle East's medical curricula which follow the, traditional teacher-oriented approach. Moreover, minimal efforts have been made to adequately encourage medical students to achieve formal research training [23]. It can be said that constructing a robust research environment in Middle East continues to be a challenge and a major problem to overcome [13]. Committed to the highest international standards of undergraduate excellence in academics and research, Alfaisal University Medical School is an exceptional example of an institution that integrates an inspirational medical education and research-based, oriented, led, and tutored program.

Alfaisal University Medical College is a recently launched, private, non-profit, student-centered, and research-based institute. Its vision is to become a supreme teaching- and research-oriented university committed to improvement in science. Its mission is to spread knowledge through an outstanding undergraduate medical education and research programs. These programs are intended to promote clinician-scientist's generations and supplement undergraduates with the best practices to muddle through the contemporary healthcare confronts. Undergraduate research has a high profile in the institution. To that end, in the summer months of 2012, Alfaisal University Medical College in Riyadh, Kingdom of Saudi Arabia, continued a tradition of sending out its promising undergraduate medical students to internationally recognized research centers of excellence. This report describes a specific collaboration with one such center, i.e., Texas A&M Health Science Center (TAMHSC)-College of Medicine (COM), in Temple, Texas, USA.

TAMHSC-COM was founded in 1999. It is in Temple, Texas, United States of America. Temple, also called "Wildflower of Capital Texas", has almost 66,000 residents and is known for its strength as a premium provincial medical center. The mission of TAMHSC-COM is to promote well-being and the best delivery of healthcare services across the region, nation, and the world through excellence in medical education and research opportunities. Research is conducted through basic and clinical science departments as well as through research-based institutes that are affiliated with TAMHSC-COM. Of note, such affiliations include the highly distinguished well-respected White and Scott Memorial Hospital. Being a land-grant institution with innovative research facilities, various local, regional, governmental, and federal agencies charitably provide funds, such as National Institute of Health (NIH) and National Science Foundation (NSF). In 2010, TAMHSC-COM has netted almost 33.1 million in research expenditures, some of which were translated into pioneering discoveries. Current research interests include neuroscience, cell biology, cardiovascular and integrative biology, cancer, and infectious disease. Therefore, TAMHSC-COM is a very fertile environment committed to educating prospective undergraduate physician-scientists about the diverse facets of biomedical research.

In this article, we report the experience and students' evaluative perceptions of this innovative collaborative educational endeavor. Furthermore, we examine how this experience could have influenced students' attitudes towards interest in scientific research and physician-scientist career appeal.

Methods

The international summer biomedical research program took place at TAMHSC-COM, Division of Investigative Pathology, and White and Scott Memorial Hospital and Clinic in Temple, Texas, USA. The program was conducted during the summer months of 2012 and lasted for exactly four weeks. A total of fourteen undergraduate medical students from Alfaisal University Medical College participated in the program. Students resided at University Courtyard Rental per the program's recommendations. Transportation services were generously provided. Sixty percent (60%) of the students' personal expenses were covered by a charitable grant from Alfaisal University Medical College. No stipends were offered to students. More than twenty-five resource individuals were involved in supervising, mentoring, and teaching the students. The resource individuals included a variety of administrative assistants, faculty members, postdoctoral researchers, lab technicians, graduate students, medical doctors, and surgeons. On the first day, students completed their registration paperwork. Then, students were provided an overview of the program's objectives and a comprehensive orientation to all research facilities. After that, to break the ice and cultural boundaries, students were invited to a friendly lunch gathering and were introduced to all resource individuals. The summer biomedical research program was designed to expose undergraduate medical students to four domains: 1) an intensive basic science research experience theoretically and practically, 2) extraordinary aspects of clinical medicine, 3) collaborative research projects, and 4) social entertaining activities. Table 1 shows a representative timetable for one of the weeks of the program.

The intensive basic science research experience included exposure to theoretical and practical sessions. The theoretical sessions used to take place in the morning from 9:00 AM to 12:00 PM. During these sessions, students were lectured about principles of laboratory biosafety, scientific research concepts and innovative laboratory-based techniques. The theoretical sessions were lectured by instructors who were among the best in the field of the lecture subject. Moreover, the theoretical sessions were conducted in modern classrooms with high technology, and were always taught through an interactive inquiry-based learning mode. Furthermore, at the end of each lecture, students were provided educational materials as hard and soft (electronic) copies to foster understanding and stimulate interest. These educational materials were kept in binders and USB flash drives to serve as easily accessible resource materials whenever needed. Each theoretical session was followed by a practical session about the same theoretical subject to supplement hands-on. The practical sessions used to take place in the afternoon from 1:00 to 5:00 PM. Prior to the start of each practical session; students were given summarized handouts about the laboratory technique: brief history, fundamental concepts, steps, cautions, applications, advantages, and disadvantages. The practical sessions were designed to ensure: a) adequate hands-on experience, and b) proper carrying out of laboratory protocols. To that end, students were mentored in small groups, in an instructor to a student ratio of 1:4. The instructor used to carry out the laboratory protocol firstly, and then students would carry out the same laboratory protocol individually. A check-list was used to determine whether the student had carried out all steps successfully. In case of a failed execution

Date	Morning Activities (09:00 to 12:00 PM)	Lunch Time (12:00 to 01:00 PM)	Afternoon Activities (01:00 to 05:00 PM)	Evening Activities (After 5:00 PM)
Monday 09 July 2012	Registration Summer Research Program Overview (Lecture) Orientation to research facilities (Site Tour)	Friendly lunch gathering for all students and program's resource individuals	Basic Laboratory and Clinical Safety Training (Lecture) Confidentiality Training (Lecture)	Welcoming dinner at the residence of the program Director
Tuesday 10 July 2012	Tissue culture (Lecture)		Tissue culture (Practical)	Temple Mall (Site Tour)
Wednesday 11 July 2012	Western Blot Analysis (Lecture)		Western Blot Analysis (Practical 1/2)	Summit Gym (Site Tour)
Thursday 12 July 2012	Western Blot Analysis (Practical 2/2)			Premiere Cinema (Site Tour)
Friday 13 July 2012	Deep Brain Simulation in the treatment of Parkinson's Disease (Special Talk) Scott & White Hospital's Simulation Center and Robotic Surgical Ward (Site Tour)		Time allotted to work on the Collaborative Research Project	Free time
Saturday 14 July 2012	Trip to Six Flags Festival and Sea World, San Antonio, Texas, USA			
Sunday 15 July 2012	Free time Time allotted to work on the Collaborative Research Project (optional and if needed)			

Table 1: Timetable for the first week of summer research program.

Tissue Culture Techniques
- Basics of cell biology
- Tumor biology
- Work area and equipment usage
- Tissue culture techniques
- Cryopreservation(cell cooling to low sub-zero temperatures)
- Growth requirements
- Cell lines maintenance of aseptic conditions.
- Culturing of adherent and suspension cells.
- Resuscitation of frozen cells.
- Prevention of contamination and 3D-cell culturing
- Cell morphology, counting, maintenance and passages of different cancer cell lines
- The use of *Caenorhabditis elegans (C. elegans)* as an animal model for drug discovery of Type 2 Diabetes Mellitus

Protein Estimation and Sodium Dodecyl Sulfate-Polyacrylamide Gel Electrophoresis (SDS-PAGE)
- Protein structure
- Protein sample preparation from cells and tissues
- Depletion methods
- Estimation of proteins
- Protein Estimation - Lowry Method
- SDS-PAGE gel preparation and electrophoresis
- Protein visualization on the gel

Western Blot Analysis
- Sample preparation
- Gel electrophoresis
- Protein transfer to membrane
- Blocking of membrane
- Conjugation of primary and secondary antibodies
- Detection methods
- Analysis
- Reprobing of membrane

Enzyme Linked Immunosorbent Assay (ELISA)
- Principle of immunoassay
- Competitive and non-competitive immunoassay.
- Direct, indirect and sandwich ELISA
- Sample preparation
- Pre-coating of ELISA plate
- ELISA protocol
- Color development
- Reading ELISA plates
- Applications of ELISA

Ribonucleic Acid (RNA) Isolation
- RNA structures, functions and types
- RNA transcription, genetic code and translation
- RNA synthesis and isolation
- Handling and storage of RNA
- RNA Visualization
- RNA Applications

Reverse Transcription-Polymerase Chain Reaction (RT-PCR) • PCR background, types and methods • Designing of PCR primers • Optimization of PCR • PCR applications • cDNA synthesis • Setting up RT-PCR • PCR quantitation, dissociation curves and amplification plots
Transfection • Transfection methods • Transient and stable transfection • Mammalian expression vectors • Transfection assay • Factors influencing transfection efficiency • Applications • Protocols for stable cell line preparation and plasmid DNA transfection
Complementary Deoxyribonucleic Acid DNA (cDNA) • Basics of cDNA, cDNA library • Messenger RNA (mRNA) extraction • cDNA construction • cDNA synthesis, applications, history, structure and replication of DNA
RNA Interference (RNAi) Technology • RNA interference • Small interfering RNA biogenesis • Small interfering RNA (siRNA) mechanism • Biochemical mechanism of RNAi • Antisense technology challenges • Inducing RNAi in mammalian cells • siRNA applications. • siRNA synthesis and design • siRNA delivery
Two-Dimensional Sodium Dodecyl Sulfate-Polyacrylamide Gel Electrophoresis (2D SDS-PAGE) • Basics of 2D gel • Isoelectric point • 2D sample preparation for bacterial cells, plant tissues, yeast cells • Protein solubilization reagents • Cell disruption methods • Software analysis
High Pressure Liquid Chromatography (HPLC) • Pillar proteomic technologies • Principle and instrumentation of chromatography, affinity chromatography, size exclusion chromatography, ion-exchange chromatography, high pressure liquid chromatography, reverse phase chromatography • Types of columns and solvents
Mass Spectrometry • Proteomics approach, challenges, components and instrumentation • Basic proteomic analysis scheme • Sample preparation details • Principle and instrumentation of micro fractionation unit • Principle and characteristics of mass spectrometer, types of ion source and mass analyzers. • Protein digestion, posttranslational modifications. • Comparative proteomic profiling, bottom up approach. • Database searching by Mascot, Spectrum Mill and ProteinCenter for biomarker discovery and pathway network analysis, quantitation, applications and limitations
Basic Laboratory and Clinical Safety Training • Scott & White Compliance Officers provided Basic Laboratory and Clinical Safety Training which includes the required information for working with chemical and biological agents
Confidentiality Training • *Scott & White Compliance Officers provided training on confidentiality and privacy and record keeping policy and procedures*

Table 2: Basic science research topics covered during the program.

of a step, the student could repeat until successful execution of the laboratory step was achieved. Students were also given opportunities to join their instructors during off-working hours and weekends should they need any help with any laboratory protocol. Table 2 shows a list of topics covered theoretically and practically during the program.

Generally, the goals of the intensive basic science research experience were to: 1) gain fundamental principles of scientific basic science research and *in vitro* molecular biology methodologies, 2) comprehend such principles when encountered in future scientific literature, 3) recognize obstacles faced by scientists, 4) appreciate the enormous efforts spent by scientists in the endeavors of advancing biomedical sciences, 5) encourage enthusiasm to carry out groundbreaking discoveries through basic science research, 6) acquire competent and proficient execution of laboratory protocols, 7) promote interest and appreciation of considering a prospective physician-scientist career, and 8) enhance critical appraisal, problem-solving and life-long learning skills.

In addition, throughout the program, and to make the research experience more exciting and productive, students were exposed to extraordinary aspects of clinical medicine. That was achieved through arrangements of: a) special talk series, and b) site tours. The special talk series were made sure to be: 1) diverse in the subjects of medical specialties, 2) suitable to the academic educational level, 3) relevant to the current clinical practice, 4) inspiring for pursuit of

Name	Title	Role/Expertise
Dr. Alexzander Asea	Effie and Wofford Cain Centennial Chair in Clinical Pathology and Director, Division of Investigative Pathology, Baylor Scott and White Healthcare and Texas A&M Health Science Center College of Medicine (USA)	Program Director, Mentor and Teacher with expertise in cancer and diabetes research. Lead clinical facilities tours (Pathology, Radiation Oncology, Robotic surgery). Gave lectures on oral and poster presentations
Dr. Punit Kaur	Assistant Professor of Pathology and Laboratory Medicine and Assistant Director, Proteomics Core Facility, Baylor Scott & White Healthcare and Texas A&M Health Science Center College of Medicine (USA)	Program Supervisor, Mentor and Teacher with expertise in cell biology and protein chemistry, Lead research lab tours (Regenerative Medicine, cGMP facility, College Station Campus, Medical Education Building), Social tours (Texas State Capital, George Bush Library and Museum, Kyle Football Stadium, National Aeronautics and Space Administration)
Dr. Nagaraja Mallappa	Assistant Professor of Pathology and Laboratory Medicine, Baylor Scott & White Healthcare and Texas A&M Health Science Center College of Medicine (USA)	Teacher in cell biology and tissue culture techniques with expertise in RNAi interference technology and cDNA, transfection
Dr. Paola Rosas	Graduate Student, Texas A&M University College of Medicine (USA)	Teacher tissue culture with expertise in Type 2 diabetes, C. *elegans* as an animal model
Dr. Dawit Gizachew	Associate Professor, Department of Surgery, Baylor Scott & White Healthcare and Texas A&M Health Science Center College of Medicine (USA)	Teacher in deep brain simulation, with expertise in Trauma Surgery
Dr. Samuel Forjuoh	Professor of Family Medicine, Baylor Scott & White Healthcare and Texas A&M Health Science Center College of Medicine (USA)	Teacher in obesity in children with expertise in Family Medicine
Dr. Alexander Panossian	Professor and Head of Research and Development, Swedish Herbal Institute (Sweden)	Teacher in uses of plant adaptogens in neuroscience with expertise in pharmaceutical research and adaptogen research

Table 3: Faculty and their role in the program.

Special emphasis series	Site tours
Heat Shock Proteins and Type 2 Diabetes Mellitus: A Conformational Disease *C. elegans* as an Animal Model for Drug Discovery of Type 2 Diabetes Deep Brain Simulation in the Treatment of Parkinson's Disease Conducting Clinical Research in Primary Care Adaptogens: Evidence-Based Effectiveness and Mechanisms of Actions How to Present a Winning Oral and Poster Presentation	Scott & White Hospital's Anatomic Pathology and Clinical Pathology (Temple, Texas) Scott & White Hospital Department of Radiation Oncology (Temple, Texas) Scott & White Hospital's Robotic Surgical Ward (Temple, Texas) Tour of Scott & White Hospital's Simulation Center, (Temple, Texas) Temple College's Simulation Center (Temple, Texas) Texas A&M Health Science Center College of Medicine Institute of Regenerative Medicine (Temple, Texas) Texas A&M Health Science Center College of Medicine Cancer Research cGMP Facility (Temple, Texas) Texas A&M Health Science Center College of Medicine Bryan/College Station Campus (Bryan-College Station, Texas) Tours of Medical Research Education Building (MREB), Simulation Center (SIMS), TAMHSC College of Medicine, Health Professions Education Building (HPEB) and TAMU Campus (Bryan-College Station, Texas)

Table 4: List of the special emphasis series and site tours scheduled during the program.

innovation, 5) extraordinary, 6) fostering medical terminology, 7) highlighting the up-to-date revolutionary discoveries, 8) augmenting awareness to contribute to community-based studies, 9) shedding light on the significance of "physician-scientists" and "translational research" concepts, and 10) underlining research future directions in medical sciences and clinical practice. The special talk series used to take place once per week. They were instructed by Professors who are role models and known for their pioneering contributions to the subject of the special talk as shown in Table 3. To make exposure to clinical medicine even more attractive and practical, site tours were arranged throughout the program. The site tours were arranged as such to: 1) foster understanding of basic biomedical research and clinical medicine concepts, 2) explore modern advances in biomedical diagnostics, therapeutics, and clinical technologies, and 3) provide a sense of enjoyment and hands-on-experience. Table 4 shows a list of the special talk series and site tours scheduled during the program. At the beginning of each site tour, students were given an agenda and a set of objectives to cover. And, at the end, students were given handouts and brochures as resource materials. Table 5 shows an agenda for one of the arranged site tours. The partner for the initiative of arranging most of the site tours was White and Scott Memorial Hospital and Clinic in Temple, Texas, USA.

To further reinforce critical thinking skills and give the students a true taste of genuine research, throughout the program and along with the teaching activities, students were divided into four groups. Each group consisted of four to five students and one faculty research mentor. Each group was assigned to work on a collaborative research project to be presented at the end of the program. Each group was introduced to the scientific background of the research project, its anticipated methodology, expected results, and potential implications in clinical practice. Time allotted to work on the collaborative research projects used to take place mainly in Wednesdays. Free times, students efficiently and smartly utilized lunch breaks and weekends to carry on their collaborative research projects whenever needed. Moreover, research group meetings were held regularly throughout the program

1. Welcoming the students
2. Theoretical session (interactive-based lecture)
   A. Introduction to Radiation
      • Definition (physics), Discovery, Types, Uses of radiation
   B. Introduction to Oncology:
      • Definition, Diagnosis, Prognosis, Palliative care, Ethical issues, Research, Specialties
   C. Introduction to Radiation Oncology:
      • History, Definition, Important terms, Mechanism of action, Dosages, Effects on cancer cells, Side effects, Types, Future research directions
3. Practical session (tour around the facilities, clinics and hands-on-experience)
4. Answer/Question session
5. Giving out handouts and appropriate brochures
6. The end of site tour

Table 5: Agenda for the arranged site tour to Scott & White Memorial Hospital's Department of Radiation Oncology.

Project title	Participants
Silencing the HSP27 gene suppresses growth and migration capabilities of Panc-1 cells	Abdullah Sarkar, Afzal A Alam, Haneen H Baitalmal, Mohammad OZ Haqueequllah, Mohamad SME Alkodaymi, Khaled M AlKattan, Ganachari M Nagaraja and Alexzander AA Asea
Upregulation of heat shock protein 72 (Hsp72) expression in rhabdomyosacarcoma cells	Fatimah Al-Ghamdi, Hamad W Al-Thumairy, Arafat M Khondokar, Sarah Qureshi, Khaled M AlKattan, Punit Kaur and Alexzander AA Asea
Role of heat shock proteins in the prevention of h-IAPP aggregation in Type 2 diabetes mellitus	Abdalla M Gazal, Abdullah M AbuNimer, Kawther A Almuttalebi, Salman M Alshakaki, Waseem M Saadeh, Khaled M AlKattan, Paola C Rosas and Alexzander AA Asea

Table 6: Titles and participants in collaborative research projects.

Social Activities
- Welcome dinner at the residence of the Program Director, Dr. Alexzander AA Asea (Belton, Texas)
- Group dinner organized by Alfaisal Medical Students at the University Courtyard Residence (Temple, Texas)
- Parties and picnics organized by the Alfaisal Medical Students at the local parks (Temple, Texas)

Cultural Activities
- Tour of Texas State Capital, Austin, Texas
- George Bush Presidential Library and Museum, College Station, Texas
- Kyle Field Football Stadium, College Station, Texas
- The Alamo and River Walk, San Antonio, Texas
- National Aeronautics and Space Administration (NASA) - Johnson Space Center, Houston, Texas

Recreational Activities
- Six Flags Fiesta Texas, San Antonio, Texas
- Sea World, San Antonio, Texas
- Cameron Park Zoo, Waco, Texas

Shopping
- Temple Mall, Temple, Texas
- San Marcos Premium Outlet Mall, San Marcos, Texas

Table 7: List of the off-campus entertaining activities organized during the program.

during workdays and weekends. These meetings used to serve as tutoring practical sessions and to discuss research progress reports, feedbacks, and other important topics. Such topics included ethics in scientific research, how to effectively search in scientific literature databases, note taking, time management, team work, professional presentation, and scientific writing skills. Students had to keep records and/or logbooks of all their activities.

At the end of the program, students presented their collaborative research projects as poster presentations to a well-regarded audience comprised of the program's resource individuals in addition to visiting members from TAMHSC-COM and White and Scott Memorial Hospital and Clinic. A dinner farewell and awarding ceremony followed this. The summaries of the poster presentations were submitted, evaluated, and accepted to be presented at The Sixth International Symposium on Heat Shock Proteins in Biology and Medicine in association with Cell Stress Society International, in November 3rd-November 7th, 2012, in Washington, DC, USA. All the students' summaries had interesting findings and would be translated into publications in the very near future. Table 6 shows the titles and authors of the collaborative research projects. The aim of collaborative research projects was to provide a space to foster students' understanding of scientific research, supplement hands-on experience, and develop critical thinking, problem-solving and team work skills.

For most students, it was the first time to visit USA, generally, and Texas, specifically, and hence, it was necessary to expose them to a sort of Texan social entertaining experience. To that end, apart from the training and educational aspects of the summer research program, off- and on- campus social, cultural, and recreational activities were arranged. Some activities were arranged by the program and others by students, during weekdays and weekends. Arranged by the program, upon arrival, a traditional dinner warm-heartedly welcomed students, "Tex Mex", hosted at the residence of the program director, Dr. Asea. Moreover, during weekends, memorable entertaining trips were arranged to NASA (Houston), Sea World (San Antonio), Six Flags (Dallas), the State Capital (Austin), TAMHSC-Bryan/College Station campus (College Station), Kyle Field Football Stadium (College Station) and George Bush Presidential Library and Museum (College Station). Arranged by students, several amusing activities were planned, such as an adrenaline gushing skydiving experience, enjoyable outgoing hangouts at Temple Mall where many movies were watched in 3D, and an entertaining shopping spree at the San Marcos Outlet Mall (San Marcos). Throughout the program, regular social gatherings with mentors and other Texan summer students were maintained, which included dinner parties and picnics to local parks. Being 7,000 miles away from homeland for the first time, the entertaining experience was worthwhile. These social activities provided students with friendly-informal opportunities to interact with seniors; where all parties shared their experiences on personal and professional levels, outside the formal environment. Table 7 shows a list of the off-campus entertaining activities that were organized during the program.

After the completion of the program, all students were requested to complete an online anonymous survey using the online instrument QuestionPro (QuestionPro,Inc, Seattle, WA, USA). The survey was administered to students to assess their perceptions of this innovative research educational endeavor. Domains specifically examined by the survey included: 1) demographical data and characteristics of participants, 2) research knowledge, skills, and process gains, 3) personal and professional gains, 4) negative insights about research, 5) career clarification and probability for a research career appeal, and 6) overall evaluation of the summer research experience. A typical 5-level Likert rating scale was used for evaluating each surveyed item as follows (1 - Strongly Disagree, 2 - Disagree, 3 - Neutral, 4 - Agree, 5 - Strongly Agree). For ease and convenience of analyzing data, disagreement responses of (1 - Strongly Disagree and 2 - Disagree,) were grouped as "Disagree", whereas agreement responses of (4 - Agree and 5 - Strongly Agree) were grouped as "Agree".

Category	n (%)
Gender	
Male	10 (71)
Female	4 (29)
Academic Year	
1st year medical student	10 (71)
2nd year medical student	4 (29)
Nationality	
Saudi	3 (21)
Non-Saudi	11 (79)
Has good knowledge of research	
Yes	2 (14)
No	12 (86)
Previous basic science research experience	
Yes	1 (7)
No	13 (93)
Has presented a research project before	
Yes	1 (7)
No	13 (93)
Has a determined desire to become a physician-scientist	
Yes	1 (7)
No	13 (93)
Probability to get involved in research activities in the future	
High	3 (21)
Moderate	6 (43)
Low	5 (36)

Table 8: Demographical and characteristics data of the participants.

Results

Demographical data and characteristics of the participants

Fourteen undergraduate medical students from Alfaisal University Medical College participated in the program. Fourteen students responded to the survey with a response rate of 100%. Table 8 shows the demographical data and characteristics of the participants. Among the participants, 10 students (71%) were males and 4 students (29%) were females. Ten students (71%) were first year medical students and 4 students (29%) were second year medical students. Three students (21%) were Saudi nationals and 11 students (79%) were non-Saudi nationals from various backgrounds. Considering students' sufficient acquisition of research knowledge and skills, 2 students (14%) replied with "yes" and 12 students (86%) replied with "no". Interestingly, only 1 student (7%) had a previous summer research experience and presented a basic science research project locally, whereas the majority 13 students (93%) neither had a previous basic science research experience nor presented a basic science research project locally. This was expected as students did not get the chance to get them involved in on- and off-campus research activities, due to the academic commitment overload and lack of time. Exploring whether students have determined desires to pursue a physician-scientist or academic medicine career, 13 students (93%) replied with "no", whereas only 1

Category and Evaluative items	Disagree n (%)	Neutral n (%)	Agree n (%)
• Increased fundamental knowledge of research	1 (7)	1 (7)	12 (86)
• Increased using primary scientific literature appropriately	1 (7)	2 (14)	11 (79)
• Increased understanding of encountered scientific literature methodology	2 (14)	1(7)	11 (79)
• Increased theoretical research skills	1 (7)	1 (7)	12 (86)
• Increased practical/technical research skills	0 (0)	1 (7)	12 (93)
• Increased understanding of ethical research conducts	4 (29)	7 (50)	3 (21)
• Increased understanding of assertions require evidences	0 (0)	3 (21)	11 (79)
• Increased skills of designing a complete research project	3 (21)	7 (50)	4 (29)
• Increased skills of formulating research questions	3 (21)	4 (29)	7(50)
• Increased skills of observing and gathering data	1 (7)	4 (29)	9 (64)
• Increased skills of analyzing data appropriately	4 (29)	4 (29)	6 (43)
• Increased skills of using appropriate statistical analysis methods	5 (36)	7 (50)	2 (14)
• Increased skills of drawing conclusions and critically discussing them	1 (7)	3 (21)	10 (71)
• Increased skills of directing future plans/experiments	1 (7)	3 (21)	10 (71)
• Increased skills of outlining limitations in the research study	0 (0)	4 (29)	10 (71)
• Increased critical thinking skills	1 (7)	1 (7)	12 (86)
• Increased problem solving skills	1 (7)	1 (7)	12 (86)
• Increased life-long learning skills	0 (0)	3 (21)	11 (79)
• Increased research-related oral communication skills	0 (0)	1 (7)	13 (93)
• Increased scientific research writing skills	3 (21)	7 (50)	4 (29)
• Increased appreciation of time and efforts spent by physician-scientist to advance science	1 (7)	0 (0)	13 (93)
• Increased understanding of uncertainty/unpredictability of research process	0 (0)	2 (14)	12 (86)
• Increased recognition of obstacles/challenges faced by physician-scientists	0 (0)	4 (29)	10 (71)
• Increased appreciation of research to improve healthcare	0 (0)	1 (7)	13 (93)
• Simulated a temporary envisioned life of a physician-scientist	0 (0)	3 (21)	11 (79)
• Increased ability to think and work like a physician-scientist	1 (7)	1 (7)	12 (86)

Table 9: Students' perceptions about gains in research process, knowledge and skills.

Category and Evaluative items	Disagree n (%)	Neutral n (%)	Agree n (%)
• Increased self-confidence	0 (0)	2 (14)	12 (86)
• Increased independent self-thinking	0 (0)	2 (14)	12 (86)
• Increased independent self-learning	0 (0)	2 (14)	12 (86)
• Increased independent self-working	0 (0)	2 (14)	12 (86)
• Increased motivation, determination, persistence, dedication and commitment to achieve goals	0 (0)	1 (7)	13 (93)
• Increased learning from mistakes and setbacks	1 (7)	3 (21)	10 (71)
• Increased problem-oriented thinking	0 (0)	2 (14)	12 (86)
• Increased teamwork skills	1 (7)	1 (7)	12 (86)
• Increased communication skills	0 (0)	2 (14)	12 (86)
• Increased adherence to honesty, frankness and ethical behaviors and attitudes	0 (0)	1 (7)	13 (93)
• Strengthened academic and professional resume (curriculum vitae)	0 (0)	1 (7)	13 (93)
• Increased potential for manuscript publications	1 (7)	2 (14)	11 (79)
• Increased potential for abstract presentation locally and internationally	0 (0)	0 (0)	14 (100)
• Expanded friendly relationships with faculty members and peers	0 (0)	2 (14)	12 (86)
• Attained recommendation letters	0 (0)	1 (7)	13 (93)
• Stimulated curiosity for discovery and innovation through research	0 (0)	1 (7)	13 (93)
• Provided a sense of enjoyment, enthusiasm, fun, entertainment and passion	0 (0)	1 (7)	13 (93)

Table 10: Students' perceptions about personal and professional gains.

student (7%) replied with "yes". Investigating students' probabilities to get involved in research activities in the future, 3 students (21%) expressed "high", 5 students (36%) expressed "low", and 6 students (43%) expressed "moderate" probabilities. The variable responses to a physician-scientist career appeal or involvement in research activities could be attributed to the students' inadequate exposure to the varying aspects of research process to decide.

Research process, knowledge and skills gains

Prior to participating in the summer research program, most students (93%) had very little to basic science research. However, after the completion of program, students demonstrated significant gains in the various aspects of the research process, knowledge, and skills as displayed in Table 9. The most self-reported gains by students were "increased fundamental knowledge of research" (86%), "increased using primary scientific literature appropriately" (79%) and "increased understanding of encountered scientific literature methodology" (79%). In addition to that, students reported "increased theoretical research skills" (86%), "increased practical/technical research skills" (93%) and "increased understanding of assertions require evidences" (79%). Intriguingly, the intensive basic science research experience allowed students to envision a life of a physician-scientist (79%), enhanced their abilities to think and work like one (86%) and elucidated the importance of research to improve patient care (93%). Moreover, the experience gave them an insight on how to handle the high levels of frustration and unpredictability involved in a research career (86%) and eventually increased their appreciation of time and efforts spent by physician-scientists to advance the science of medicine through research (93%). Besides this, the experience provided them with an opportunity to develop their critical appraisal (86%), problem-solving (86%), life-long learning (79%), teamwork (86%) and research-related oral communication (93%) skills.

The students reported acceptable gains in research process, from designing complete research projects (29%), to formulating hypotheses (50%), to gathering data (68%) and to analyzing them critically (43%). The gains in research process were not significantly reported by students, and this was anticipated for two reasons. First, students had limited research background as they were enrolled in an MBBS program which did not require a bachelor's degree of science prior to entering medical school. Second, these critical competencies are generally acquired satisfactorily over time and with subsequent experiences and are not gained right away. Moreover, students expressed that they would need more expertise and practice to reach a level where they would be able to run a study on their own with limited or no supervision. The least self-reported gains were "increased using of statistical analysis methods appropriately" (14%), "increased understanding of research ethical conducts" (21%) and "increased scientific research writing skills" (29%). These findings mirrored similar findings in another study [8]. This was anticipated as most of the students were still at a very early stage of medical education and were not yet exposed sufficiently to these competencies during research-focused lessons in scientific research, statistics, epidemiology, and community medicine courses. However, appropriate measures to enhance these three competencies would be taken into consideration in the future.

Personal and professional gains

Students' listed personal and professional gains as one of the most important learning outcomes of this research internship as depicted in Table 10. Students showed a consistent competency development in nearly all aspects of a well-rounded scientist. Majority of students (86%) reported increased independent self-confidence, self-learning, self-thinking, self-working, problem-oriented appraisal, team work and communication skills. Furthermore, almost all students (93%) reported increased commitment to achieve goals and adherence to ethical attitudes and behaviors. Moreover, various students reported significant building up of curriculum vitae (93%), increased potential for manuscript publication (79%), greater possibility for abstract presentation locally and internationally (100%), and making collegial relationships with scientific community members (86%). Interestingly, the majority (93%) expressed a sense of enjoyment associated with research work.

Negative insights about research

Being the first time for majority of students to get exposed to research, they had some positive as well as negative viewpoints about the research environment. Table 11 shows the students' negative insights about research. Almost all students (71%) commented on the complexity of science and the stressful nature of research. Some students expressed time (79%) and effort (86%) consuming nature of the research field in return for a low income (79%) as reasons why a research career might not be desired. Others reported the following as obstacles to pursuing a physician-scientist career: difficulty to obtain

Category and Evaluative items	Disagree n (%)	Neutral n (%)	Agree n (%)
• Time-consuming career	2 (14)	1(7)	11 (79)
• Effort-consuming career	1 (7)	1 (7)	12 (86)
• Stressful career	0 (0)	4 (29)	10 (71)
• Low-income career	2 (14)	1 (7)	11 (79)
• Very senior competitive colleagues in the research society	2 (14)	5 (36)	7 (50)
• Very difficult to get funding grants nowadays	0 (0)	3 (21)	11 (79)
• Increased pressure on physician-scientists to write grants and/or publish manuscripts	0 (0)	4 (29)	10 (71)
• Not able to finish projects on time for any reason	0 (0)	2 (14)	12 (86)
• Complexity of science	0 (0)	4 (29)	10 (71)

Table 11: Students' perceptions about negative insights about research.

Category and Evaluative items	Disagree n (%)	Undecided n (%)	Agree n (%)
• Clarified career pathway	0 (0)	2 (14)	12 (86)
• Increased motivation for a future physician-scientist professional career	0 (0)	3 (21)	11 (79)
• Increased tendency to pursue an M.D./Ph.D. degree	0 (0)	2 (14)	12 (86)
• Increased probability to carrying out some research activities along the medical career	0 (0)	1 (7)	13 (93)
• Has a determined desire to become a physician scientist	1 (7)	7 (50)	6 (43)

Table 12: The impact of the summer research program on students' career clarification, attitudes towards scientific research and likelihood for pursing a prospective physician-scientist career.

funding grants currently (79%), being not able to finish projects on time for any reason (86%) and the subsequent increased pressure and stress on researchers to publish manuscripts (71%).

Career clarification, attitudes towards scientific research and probability for a physician-scientist career

Table 12 shows the impact of the summer research program on students' career clarification, attitudes towards scientific research and likelihood for pursing a prospective physician-scientist career. Majority of students (86%) indicated that the simulated research experience clarified and aided in the decision-making of their future professional careers. The program positively affected students' attitudes towards participation in scientific research. Due to the excitement and bliss nature of research in discovery and innovation, fascinatingly, most students (86%) started considering the prestigious dual-track MD/PhD degree as a prime future choice. Moreover, 13 students (93%) demonstrated an increased desire to get involved in research activities along their medical careers. Interestingly, more than three-quarters (79%) agreed or strongly agreed that the experience increased their motivation to become physician-scientists. If note, 6 students (43%) expressed determined desires to purse physician-scientist careers by the end of the program (versus only 1 student (7%) before the start of the program).

Overall evaluation of the summer research experience

To assess the pros and cons of the program, a formal evaluative survey was run. Table 13 shows students' perceptions of the overall evaluation of the summer research experience. The survey examined 7 domains: 1) administrative assistance, 2) intensive basic science research experience, 3) exposure to extraordinary aspects of clinical medicine, 4) social entertaining activities, 5) summer research program achievements, 6) recommendation of the program to other students, and 7) overall evaluation of program. As shown in Table 13, the overall program was regarded to be uniformly positive in all its aspects. More than three quarters of students (77%) were satisfied with the smooth facilitation of their summer research experience throughout the program by the administrative staff. Moreover, majority were homogeneously satisfied with the basic science research experience from the theoretical (93%) and practical (79%) aspects. In addition, 86% of students highly complimented the special talk series and site tours. Besides, the extracurricular on-campus (79%) and off-campus (93%) recreational activities were highly cherished experiences satisfactorily reported by the students. Of note, students reported favorably on their satisfaction of the collaborative research projects (86%). Furthermore, apart from having first-author research paper (7%), majority of students were very pleased and satisfied with the overall program research-related achievements (71%). Majority of students (93%) recommended this program to their colleagues. In general, students were positively satisfied (93%) with the collective overall evaluation of this innovative summer research endeavor in all its aspects.

Discussion

The significance of physician-scientists in advancing biomedical sciences is evident [4]. Unfortunately, there has been an alarming decline in the number of prospective physicians-scientists [3,5-9,21]. Proposed measures to overcome this problem have been carried out and discussed in literature [3,7,12-19]. One influential measure to encourage a generation of physician-scientists is early exposure to research during undergraduate education [15,17,20,21]. Alfaisal University Medical College in 2012 has collaborated with TAMHSC-COM, Department of Investigative Pathology, to provide its undergraduate students with opportunities to join an avant-garde biomedical research program at world-renowned research facilities. In this paper, we report the experience and students' perceptions of this innovative educational endeavor. Moreover, how this experience could have influenced students' attitudes towards interest in scientific research and physician-scientist career appeal. As we are familiar with the recent advances in medical technology and key discoveries in biomedical research has potentially improved human health in an unprecedented fashion. Thus, many of the Arab Gulf countries are devoting increasing resources toward establishing centers of excellence in biomedical research [13]. However, environmental factors are important because the low profile of private medical institutions and their negligible endowments in the region are examples of such challenges. Also, business-type government controlled universities are not the solution for overcoming the challenges facing higher education and research programs in such countries. Therefore, not-for profit, time-tested education institutions from abroad in public-private partnership with local organizations offer favorable conditions to build

Category and Evaluative items	Disagree n (%)	Neutral n (%)	Agree n (%)
The administrative staff facilitated my summer research experience very smoothly:			
• Program application	1 (7)	1 (7)	12 (86)
• Visa paper work	0 (0)	3 (21)	11 (79)
• Arranging travel bookings	0 (0)	4 (29)	10 (71)
• Arranging accommodation bookings	0 (0)	2 (14)	12 (86)
• Arranging on- and off-working hours transportation services	1 (7)	3 (21)	10 (71)
• Arranging social events on weekdays and weekends	2 (14)	1 (7)	11 (79)
• 24/7 continuous support, guidance and assistance throughout	1 (7)	2 (14)	11 (79)
• Sufficient quantity and quality of time spent with the research mentor	1 (7)	2 (14)	11 (79)
I was satisfied with the basic science research experience:			
• Overall theoretical, dedicated, educational, informative sessions	0 (0)	1 (7)	13 (93)
• Overall practical, hands-on-experience sessions	1 (7)	2 (14)	11 (79)
I was satisfied with the exposure to attention-grapping aspects of clinical medicine:			
• Overall special talks	0 (0)	2 (14)	12 (86)
• Overall site visits/tours	1 (7)	1 (7)	12 (86)
I was satisfied with the social, cultural and recreational activities :			
• Overall on-campus activities	0 (0)	3 (21)	11 (79)
• Overall off-campus activities	0 (0)	1 (7)	13 (93)
I was satisfied with my research mentor for the collaborative research project:			
• Mentor availability, formal and informal meetings	0 (0)	2 (14)	12 (86)
• Quantity and quality of time spent	2 (14)	1 (7)	11 (79)
• Support and assistance throughout	0 (0)	1 (7)	13 (93)
• Provided research skill development	1 (7)	1 (7)	12 (86)
• Provided non-related research skill development	1 (7)	2 (14)	11 (79)
• Provided intellectual growth and development	0 (0)	3 (21)	11 (79)
• Provided professional career development	1 (7)	2 (14)	11 (79)
• Provided academic guidance	3 (21)	0 (0)	11 (71)
• Acknowledged students' contributions to research	1 (7)	1 (7)	12 (86)
• Considered students for abstracts and/or manuscripts	0 (0)	0 (0)	14 (100)
• Showed excellence and professionalism in communication, research and teaching	0 (0)	1 (7)	13 (93)
• Served as a mentor role model	1 (7)	1 (7)	12 (86)
• Overall satisfaction	0 (0)	2 (14)	12 (86)
Program research achievements:			
• I will be able to function effectively and efficiently at any given basic sconce laboratory	0 (0)	1 (7)	13 (93)
• I will have a first-author research paper	10 (71)	3 (21)	1 (7)
• I will have co-authorship in a research paper	1 (7)	4 (29)	9 (64)
• I will present my summer research project in an international meeting	0 (0)	0 (0)	14 (100)
• I will present my summer research project in a local meeting	0 (0)	0 (0)	14 (100)
• Overall satisfaction	0 (0)	4 (29)	10 (71)
I recommend this program for other undergraduate students	0 (0)	1 (7)	13 (93)
Collectively, I am satisfied with my summer research program experience in all its aspects	0 (0)	1 (7)	13 (93)

Table 13: Students' perceptions of the overall evaluation of the summer research experience.

robust research programs in the region and Weill Cornell Medical College in Qatar (WCMC-Q) of Cornell University is an example such an institution had positive results [13].

Physician-scientists play a unique and critical role in medical research; however, physician-scientists are declining in number. One of the very important factors is an increasing indebtedness of medical school graduates caused by rapidly rising medical school tuition costs. However, it has demonstrated that increasing interest in research careers by medical students, steady growth of the MD-PhD pool, and a new burst of activity in the "late bloomer" pool of MDs (individuals who choose research careers in medical school or in residency training), fueled by loan repayment programs that were created by the NIH in 2002 [21]. Continued funding of these new programs, coupled with sustained support for physician-scientists committed to the pathway, will be required to maintain these positive trends [21]. Over two decades of experience with NIH-sponsored medical student research programs at two medical schools strongly support the ability of these programs to interest medical students in research and academic careers [15].

A statistically significant decline in the percentage of matriculating and graduating medical students - both men and women-who expressed strong research career intentions occurred during the decade between 1987 and 1997. Moreover, matriculating and graduating women were significantly less likely than men to indicate strong research career intentions [11]. Studies have shown its personal interest too in genders. For example, cohort data obtained by tracking individuals from matriculation to graduation revealed that women who expressed strong research career intentions upon matriculation were more likely than men to decrease their research career intentions during medical school. Three worrisome trends in the research career intentions and participation of the nation's medical students (a decade-long decline for both men and women, a large and persistent gender gap, and a negative effect of the medical school experience for women) presage

a further decline in the physician-scientist pipeline unless they are reversed promptly and decisively [11].

Another example to meet challenge of debt is by a new national program for training medical students in clinical research called Clinician Scientist Training Program (CSTP), would consist of a combined degree program in medicine (MD) and clinical research (e.g. masters in translational research or masters in clinical epidemiology) [12,14]. Clinician scientist training program: a proposal for training medical students in clinical research). Students could enroll in the program at any stage during medical school. After 3 years of medical school, students would spend at least 2 years in a combined didactic and mentored clinical research training program and then complete medical school. Students could elect to pursue more prolonged clinical research training toward a combined PhD and MD [12,14]. Sometimes, it is a big opportunity as in Norway where, Medical Student Research Program is a national education and grant scheme for medical students who wish to carry out research in parallel with their studies [20]. The purpose of the program is to increase recruitment of people with a standard medical degree to medical research. Surprisingly, the majority of students wanted to continue their research towards a PhD and, of those who had completed the Medical Student Research Program, practically all had published one or several scientific papers [20].

It is very important to have collaboration among researchers, clinicians, and pharmaceutical companies and is vital for conducting clinical trials to translate laboratory findings into clinically applicable therapeutics [1]. Therefore, push for development of novel diagnostic and therapeutic agents has allowed translational cancer research to flourish. The summer program provided students with a wide-ranging understanding and appreciation of basic science research theoretically and practically. Theoretically, the program allowed the students to experience biomedical sciences beyond the knowledge of textbooks. Moreover, it helped the students to not only be mechanically-oriented researchers, but also problem-oriented investigators who can think, contemplate, question, suggest, evaluate, decide, improve, innovate, interpret, analyze, troubleshoot, and contribute enormously to the varying aspects of the research process. Practically, the program equipped the students with the proficient laboratory skills needed to ensure mastery and competent conduction of the laboratory protocols; therefore, warranting useful functionality and efficiency at any given lab. Furthermore, the program enabled the students to collaborate with great scientists and researchers at work, providing them the chance to envision life as a scientist and researcher. Yet, this collaborative work enhanced their appreciation of teamwork efforts which is essential to their character development.

The incorporation of clinical aspects of medicine into the program was of a great importance. Yet, the implementations of special talk series and site tours were innovative in nature and greatly attained the satisfaction of students. Collectively, students gained a better appreciation of the significance of "physician-scientists" and "translational research" concepts. Furthermore, this incorporation illuminated the significance of the integration of basic science and clinical research as a cornerstone of advancing contemporary medicine and clinical sciences. Moreover, the exposure to clinical aspects of medicine was an added value to their preparation for the upcoming clinical years in medicine. It provided students with an opportunity to apply medical terminology and concepts learned during the academic teaching. Besides, students started exploring the option of perusing an academic medicine profession, or carrying out research activities along with the medical career. Also, the experience fostered students' curiosity for novel discoveries and contribution to patient-oriented and community-based research.

At the beginning of the program, students were divided into groups of 4 students and 1 research mentor. Each group was assigned to work on a collaborative research project to be presented at the end of the program. The research mentors provided the groups with research ideas, which were then expanded and built upon by the students. The poster presentations were attended and evaluated by senior research personnel including their group mentors. With the exceptions of statistical analysis and ethical considerations, the students showed a uniform improvement in all research aspects as shown in Table 9; from their material knowledge and research-related skills down to their ability to work effectively in a group to orally presenting confidently in front of an esteemed audience. The idea of the collaborative research project was implemented for two reasons. First, this initiative helped to assess students' demonstration of the various research knowledge and skills gained over the one-month period. Second, it provided students with an opportunity to apply what has been learnt and acquired during the program to real-life hands-on science experimentation. By doing so, students had an opportunity to master, and yet, further promote their research knowledge intellectually and their research skills practically. Moreover, it provided them with an opportunity to develop their interpersonal, team work and communication skills. Ultimately, this initiative provided the students with sense of achievement that was translated into the acceptance of their summaries at an international highly reputable symposium. Overall, this opportunity provided students with a space to acquire great personal and professional gains out of this summer research experience.

In addition to the research-based exposure, students had the occasion to get indulged into a diversity of social and communal activities among themselves and with individuals from other cultures and ethnicities [11]. These activities: 1) allowed the students to value and explore other backgrounds, 2) facilitated extraordinary entertainment experience, 3) developed their social and communicative skills, and 4) encouraged friendly interactions regardless of any differences. It was a fulfilling educational and socially meaningful experience to all students. As a spin-off, this enigmatic experience, students have made strong ties back in Texas and are looking forward to an opportunity to travel back the following summers to visit friends or get involved in a more advanced level of research.

Generally, the students were satisfied with the overall evaluation, design, and outcome gains of this astonishing experience academically and socially. Moreover, they strongly recommended such programs for the forthcoming medical undergraduates. In addition, this research encounter greatly helped students broadening their perspectives on the future, and many students started considering research as a promising career, making the widely popularity-gaining MD/PhD degree a one possible career pathway. Others started to have determined intentions to become physician-scientists in the future. Despite few drawbacks to research career expressed by students, majority demonstrated great curiosity to get involved in research activities beside their undergraduate education and medical profession. Engagement in undergraduate medical research stimulates interest in research and motivates students to pursue further postgraduate research degrees or enter physician-scientist careers [15,17,20,21].

This summer research program is unique in its structure in 5 aspects. First, unlike many other summer research programs that are carried on for 2 months or more, this program spans for only one month. This allows the students to have plentiful time to spend

the summer as wanted before the next academic year starts. Despite this relatively short period of duration, the program is intensive and productive in its core both theoretically and practically. The program provides its students with in-depth didactic lecture-based education, and intensive laboratory-based hands-on experience in innovative research techniques. Second, besides the ongoing research training and teaching, students are attached to research mentors. This allows the students to translate the research knowledge and skills acquired from this educational research training into individual and/or joint research projects. By doing so, this will provide students with a sense of a great accomplishment, maximize their benefits and serve as an added value to their curriculum vitae. To our knowledge, there is no such program that incorporates both dedicated educational research training and research mentorship at the same time. Third, alongside the research education and training, the program involves exposure to attractive facets of biomedical sciences and clinical medicine. This is achieved through arrangements of special talk series and site tours. The special talks are provided to serve as a boosting up stimulating appetizer for a medicine career. Moreover, the special talks are oriented to be out of the ordinary in nature, shedding light on translational research concepts, stimulating the search for innovative discoveries and highlighting the future research-directed goals in biomedical sciences. The site tours are conducted to provide hands-on experience and better visualization of some of the concepts delivered through the special talks. Furthermore, the tours are carried out to expose students to recent advances in biomedical diagnostics, therapeutics, and clinical technologies. In addition, students are given the opportunity to access, explore and join the various departments of Scott and White Memorial Hospital at their free times. Up to our knowledge, no other program does this. Fourth, we are not aware of any summer research training program in Saudi Arabia that formally sends female students abroad to gain research experience. This program sheds light on the importance of women as important key players in civilization prosperity and science development. Moreover, this program serves as a valuable means to regenerate the "female" physician-scientist pipeline career in the Saudi Arabia, a serious national problem to overcome. Furthermore, this program opens the floor to female students to disclose their concealed research-based creativity and inventiveness nature in advancing the science of medicine. In addition, this program encourages female students to seek leadership positions in the administrations of medical research institutions as their male counterparts. Of note, this program is specifically designed for Alfaisal's freshmen and sophomore male and female students. No other students will be able to join this program. Fifth, being the program conducted in an international country, the program is formulated to include a fair load of social entertaining activities. Such activities include friendly outgoings and trips to national sightseeing and museums. These activities are meant to serve as a breath of a sigh of the daily formal educational research experience. Moreover, they are meant to keep the students interested and motivated throughout their research internship. In addition, these activities open the floor to students to strengthen their friendships, interact with individuals from varying backgrounds, and ultimately, promote social and communicative development of their characters on personal and professional levels. Considering intensive well-rounded social entertaining activities as a cornerstone of the program's objectives is unique to many of the research programs, up to our knowledge.

The program has been complimented by its participants and grabbed the attention of prospective partakers. Moreover, the program has been greatly commended by Alfaisal University Medical College and its Undergraduate Research Committee. Building on the success of this newly introduced pilot program, it has been planned to be run for subsequent summers. Of interest, it is expected to have a total of approximately 60 students participating in the program for the summer of 2013, and therefore generating a good pool of possible prospective physician-scientists. To further enhance the experience in the future, certain modifications have been planned. Such modifications will include introducing students to a flavor of important aspects of clinical research, thereby signifying the importance of translational research: the transition of science from laboratory-based benches to real world medical practices. Moreover, focused mini-courses on scientific research principles, epidemiology and biostatistics will be implemented to enhance student's knowledge of statistical analysis and ethical conducts. Other changes will involve introducing students to *in-vivo* laboratory techniques and immunohistopathology, which are other important aspects of biomedical research enterprise. In addition, such adjustments will include increasing the workforce of mentors, making the student to mentor ratio 3 to 1. More modifications will include extending the duration of program from 4 weeks to 10 weeks. The extra 6 weeks will be utilized to get the trained students involved in enduring research projects that will be translated into scientific publications/manuscripts. This will not only provide students with a sense of research achievement, but also will have supplementary advantages to strengthen their curriculum vitae and increase their chances to get accepted at residency and fellowship programs upon graduation. On the administrational level, it is currently being negotiated to have a formal multiyear contract agreement between both parties to accommodate roughly 60-80 Alfaisal students per summer. Also, it is being planned to establish a joint research facility at Alfaisal University Medical College Campus. Further, it has been aimed to submit grants for the summer research training program and for other joint collaborative research projects between both parties. Additionally, it has been put forward to have research exchange positions for both students and faculties at both institutes. Of interest, efforts are being made to establish the 1st International Symposium on Heat Shock Proteins in the Kingdom of Saudi Arabia.

In brief, this innovative summer research training experience allowed students to: 1) gain a comprehensive overview of fundamental principles in basic science research process, 2) attain a broad understanding of *in vitro* molecular biology methodologies theoretically and practically, 3) support partaking in research activities in the future, 4) foster a curiosity to pursue a research or academic medicine career, 5) promote interest for discovery and contribution to community-based studies, 6) recognize the current challenges and future research tendencies in medical sciences and clinical practice, and 7) develop their personal and professional characters. There were several limitations to this study. First, the sample size was not large enough to draw solid conclusions. Second, this study lacked a pre-survey assessment of students' research knowledge and skills. Third, this study lacked mentors' assessment of students' gains in research knowledge and skills upon the completion of the program. Although this innovative summer program positively influenced students' stance to research, it would be interesting to track the students prospectively to explore the impact of the summer research experience on their attitudes towards involvement in scientific research activities and physician-scientist careers. Future studies shall include exploring students perceived attitudes, interest and institutional barriers to undergraduate research, academic medicine, basic scientist, or clinical-investigator careers at the Kingdom of Saudi Arabia, and whether a full one-year of undergraduate research should be incorporated into medical curricula. Moreover, investigating gender differences and

cultural barriers towards a research career in the Kingdom of Saudi Arabia is an interesting area for investigation.

Conclusion

There is a need for medical educators to support integration of research training within medical undergraduate curriculum. Moreover, educators need to understand that interest in a research career is greatly influenced by prior educational environment, research training and experience, and probably by cultural barriers and gender differences. We hypothesize that potential candidates for physician-scientists are largely the prospective medical students. Therefore, it was necessary to explore possible methods to sufficiently target/steer them to research during their early undergraduate education. One method was through this presented innovative well-rounded undergraduate summer research training program. This reported program serves as a potentially applicable method to foster the concept of undergraduate research in Kingdom of Saudi Arabia, in a smaller scale, and in Middle East, in a larger scale. Broadly, this presented program shall hopefully open further doors and opportunities for other universities to follow our footsteps, and shall serve as a founding stone for future collaboration between medical institutes. Participation in such programs enhances research intellectual and practical skills, maintains involvement in research activities and support entry to physician-scientist careers.

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