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PEDAGOGICAL CHALLENGES AND OPPORTUNITIES IN SPORT AND ANTHROMATHEMATICS

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Abstract

This paper describes pedagogical challenges and opportunities existing in 'Program of Sport and Anthromathematics'. Anthromathematics is the mathematics of human body sizes, forms, shapes and proportions, which was, formally, launched on March 22, 2010. The scheme of studies consists of formal teaching, examinations (exploring correctness of concepts and learning of techniques) and projects (non-formal development of skills). Formal teaching is based on problem-solving approach. Classroom-problem solving prepares the student to laboratory-problem solving, which, in turn, is a precursor to field-study- and industrial-problem solving. Quizzes and examinations are designed with a changed layout, SOPs prepared for invigilators and grading system simplified to reduce time for checking a script to around 4 *minutes*. Projects train the students in research-proposal preparation, planning of study, conduct of study, analysis of data using mathematical-statistical techniques and interpretation of results. The anthropometric measurements (height, mass, mid-upper-arm circumference) obtained during the conduct of project offer a wealth of learning opportunities in various disciplines — biology, chemistry, engineering, health and safety, mathematics, physics and Quranic studies. The goal is to change student's perspective and attitude towards the subject at the same time refining concepts and perfecting techniques.

Keywords: Problem-solving approach, examination pattern, research-oriented teaching, community outreach

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Introduction

Anthromathematics was introduced by the author in the Syed Firdous memorial lecture delivered during the First National Conference on Mathematical Sciences held in Department of Mathematics, University of Karachi in 2010. Defined as the mathematics of body sizes, forms, shapes and proportions, the sciences of 'anthropology' (study of human being) and 'anthropometry' (measurement of human being) take the shape of 'anthromathematics' through ideas from mathematics, *e. g.*, mathematical equations are used to approximate human-body form ('analysis' — formulae for surface area and volume of human body), discrete structures are seen in the anatomy and the physiology of human body ('algebra' — brain death defined, mathematically, through study of group structure), invariance under deformations is appreciated ('topology' — spinal column deformed because of scoliosis, kyphosis or lordosis, which is studied using static, dynamic and crystal-structure-based models), properties of numbers are studied ('number theory' — numbers giving height, mass, mid-upper-arm circumference) as well as inferences are analyzed ('logic' — upper limits of optimal mass-for-height). To appreciate the point further, an 'anthropometrist' is limited to recording heights, but an 'anthromathematician', not only, must measure heights, but also, must plan the session to be able to determine accuracy, precision and reproducibility of the techniques used. At the start of each session, the professional must align the scale at the same time ascertaining that the surface is level and checking the equipment against agreed-upon standards. At the end of every session, the incumbent must estimate consistency of collected data.

This paper discusses pedagogical challenges and opportunities offered by 'Program of Sport and Anthromathematics' approved by the Board of Studies of Department of Mathematics, University of Karachi in 2014. The program was, subsequently, approved on behalf of Board of Faculty of Science and Academic Council by the respective competent authorities. The scheme of studies may be broken down in 3 components — formal teaching, examinations and projects. The program should train the student in problem solving at various levels. The quality of an academic program depends, largely, on the evaluation system. Different examination systems are discussed as well as sample papers and solutions included in additional files.

The pedagogical opportunities provided by project-related activities may be used to refine concepts and broaden student's horizon. However, the true potential of the usefulness of these simple activities in teaching a topic that deeply affects our health, lies in the torch bearer of learning**:** "A good teacher is a master of simplification and an enemy of simplism" (Louis A. Berman).

September 4, 2013	**1st-Generation Solution (Kamal *et al.*, 2013*b*)**
September 4, 2014	**2nd-Generation Solution (Kamal *et al.*, 2014*b*)**
June 01, 2015	**3rd-Generation Solution (Kamal, 2015e)**
February 13, 2016	**4th-Generation Solution (Kamal *et al.*, 2016*a*, *b*)**

Fig. 1. Solutions of childhood-obesity problem proposed by the Anthromathematics Group, University of Karachi — first appeared in Kamal *et al.* (2016*a*)

The Evolution of Anthromathematics

There has been a long-felt need to apply the power of mathematics to the study of structures (anatomy) and functions (physiology) of the human body. Jenkins (2008) described kinship of anthropology and mathematics. ‘Anthropology’ became a quantitative science as ‘anthropometry’, which was given the rigor 6-*year* ago as ‘anthromathematics’ (Kamal, 2010; 2011*a*). Although, a relatively new branch of mathematics, 2 conferences have been held on the topic, viz. ‘the First Conference on Anthromathematics’ in 2013 and ‘the Second Conference on Anthromathematics and Sport Mathematics’ in 2014. MPhil courses, Anthromathematics I and II, and PhD courses, Modeling and Simulation of Biological Systems I and II, are being, regularly, taught in Department of Mathematics, University of Karachi (MPhil courses since 2011; PhD courses since 2010). An enthusiastic research program has, also, been established. 2 PhD (3 more submitted) and 5 MPhil degrees have been awarded. Research accomplishments in the area of child growth-and-obesity modeling may be summarized as**:**

- First- to Fourth-Generation Solutions (Figure 1) of childhood-obesity problem given (Kamal, 2015*e*; Kamal *et al.*, 2013*b*; 2014*b*; 2016*a*, *b*)
- Height- and mass-measurement techniques enhanced to least counts of 0.01 *cm (centimeter)* and 0.01 *kg (kilogram)*, respectively (Kamal, 2010), which were recently upgraded to 0.005 *cm* and 0.005 *kg*, respectively (Kamal *et al.*, 2016*b*); manual for anthropometry prepared (Kamal, 2006).
- Extension of CDC Growth Charts and Tables to include 0.01th, 0.1th, 1st, 99th, 99.9th and 99.99th percentiles, in addition to the percentile range, 3rd to 97th, so that extreme cases could be handled (Kamal & Jamil, 2014)
- Putting forward concepts of optimal mass, quantitative estimates of obesity/wasting as well as tallness/stunting both of them expressed as percentage (Kamal *et al.*, 2011*a*), estimated-adult *BMI* — *BMI* stands for body-mass index (Kamal & Jamil, 2012), build of a child (Kamal & Khan, 2015), use of height-percentile trajectories instead of growth velocity (height velocity), pseudo-gain of height/mass (Kamal *et al.*, 2014*c*),

classification of nutritional statuses (introduction of energy channelization I-III) and index representing severity of acute malnutrition (Kamal, 2015*a*).

- 'Growth-and-Obesity Roadmaps' of children and their parents giving 6 month-wise recommendations to achieve specific values of height (for children) and mass (for children and their parents) on the date of checkup for each consecutive month, along with lifestyle adjustment, diet and exercise plans (Kamal, 2015*a*; Kamal *et al.*, 2015*b*).

During the Second Conference on the subject the evolution of anthromathematics was highlighted (Kamal *et al.*, 2014*d*). The author spent about 30 *years* in the area of modeling of the human organs and 3-D bioimaging before, formally, launching the subject in 2010. The work included 3-D-modeling of the human spinal column — static (Kamal, 1982*a*; *b*; 1996*a*), dynamic (Kamal, 1996*c*) and crystal-structure-based (Kamal *et al.*, 2012). These models were able to generate shape of the spinal column from surface measurements (Kamal *et al.*, 2014*a*; 2015*a*; 2016*d*). Anthromathematics of the human spinal column was elaborated in Prof. Dr. Zainuddin Kamaluddin Kazi and Prof. Dr. Muhammed Ali Shah memorial lecture delivered during the First Conference on the subject (Kamal *et al.*, 2013*a*). Anthromathematics of MUAC (mid-upper-arm-circumference) measurement was described in invited lecture delivered during 'the International Conference on Physics and the World of Today' (Kamal *et al.*, 2011*b*). Standing-wave model of the human heart was able to generate shape of heart from surface measurements of coördinates of PMI (points of maximum intensity) of heart sounds generated from pulmonary, tricuspid and mitral valves (Kamal, 1992; Kamal & Siddiqui, 2002). Organ-shape generation from surface measurements motivated the author to think of the discipline 'anthrotopology', which was, formally, introduced during 'the International Conference on Condensed-Matter Physics and Engineering' (Kamal *et al.*, 2012). Although, Wilson (2009) mentions the word 'anthrotoplogical' in the context of urban studies that an individual acts as an anthrotolopogical record, registering aspects such as volition and the extension of urban representation, the concept is, entirely, different from the notion put forward by the author. Author's PhD work involved modeling of global-electrocortical activity of the human brain. He developed the covariant (Kamal *et al.*, 1989), the generalized-coupling (Kamal *et al.*, 1992) and the covariant-generalized-coupling (Kamal & Siddiqui, 1997) models. This exercise resulted in generation of mathematical definition of brain death using group structure (Siddiqui *et al.*, 1993), which laid the foundations of 'anthroalgebra', formally, launched 3-*year* ago (Kamal, 2013*a*). Long before officially defining 'anthroimaging' during the First Conference on Anthromathematics (Kamal, 2013*b*), the author started working in this area by

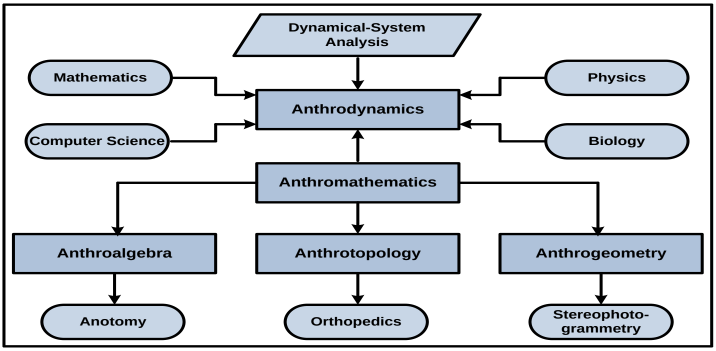

Fig. 2. The evolution of 'anthrodynamics' — first appeared in Kamal (2013*a*)

constructing a moiré frame (Kamal & Yosufzai, 1979). Main contributions were simultaneous recording of moiré and raster using selective-optical filtering for use in gait analysis (Kamal *et al.*, 1996), edge-based moiré (Kamal, 1996*b*) and edge-based raster (Kamal, 2008*a*). During 'the First Undergraduate National Computing Conference' the concept of 3-D-spinal-column surface analysis (3-D-bone scanning) by combining moiré fringe topography and rastersterography with backscatter-X-ray-scanning technology was put forward (Kamal, 2013*b*). The most-recent additions were dotted-rasterstereography (Wasim *et al.*, 2013) and dotted-raster stereophotogrammtery (Kamal, 2014*a*), the last one different from rasterstereography in the sense that stereophotogrammetric technique generates both height and curvature maps — combining the properties of moiré fringe topography and rasterstereography. Earlier, Geng *et al.* (2009) mentioned the word 'anthroImaging' only once in a detailed description of their patent application without defining or elaborating the term.

One of the areas of interest is the interaction of mathematics and sport. De Mestre (1990) wrote a monograph on the mathematics of projectiles in sport. The author highlighted role of mathematics in sport sciences and technologies in a presentation given during 'the Thirty-Fifth All Pakistan Science Conference' (Kamal, 2008*d*). Williams *et al.* (2008) discussed some basic ideas of mathematics of science and sport. Haigh (2009) reviewed such topics mainly based on probabilistic or statistical considerations. Although, Schutz (1980) delineated a field of sport studies named as sport mathematics and listed topics of study using tools of mathematical analysis, putting forward arguments, which supported the identification of mathematics and sport as a sub-discipline within sport studies and Hopper (1984) mentioned sport mathematics as a proposed research area, 'sport mathematics' as a formal subject, with a well-defined 'Program of Studies', was put forward by the author 2-*year* ago (Kamal, 2014*b*). Anthromathematics became generalized as 'anthrodynamics' (Figure 2) through

#	*Name of Branch*	*Date Introduced*	*References*
1	**Anthromathematics**	**March 22, 2010**	**Kamal (2010; 2011*a*; *b*; 2015*b*); Kamal & Jamil (2013); Kamal *et al.* (2014*d*)**
2	**Anthrotopology**	**December 27, 2012**	**Kamal *et al.* (2012)**
3	**Anthroalgebra**	**April 10, 2013**	**Kamal (2013*a*)**
4	**Anthrogeometry**	**April 10, 2013**	**Kamal (2013*a*); Wasim *et al.* (2013)**
5	**Anthrodynamics**	**April 10, 2013**	**Kamal (2013*a*); Kamal & Jamil (2013)**
6	**Anthroimaging**	**September 5, 2013**	**Kamal (2013*c*; 2014*a*); Kamal *et al.*, (2014*a*)**
7	**Sport Mathematics**	**May 17, 2014**	**Kamal (2014*b*)**
8	**Astro-Anthromathematics**	**December 29, 2015**	**Kamal (2015*c*)**
9	**Astro-Anthrodynamics**	**May 01, 2016**	**This paper**

Fig. 3. Branches of mathematics related to 'anthromathematics'

a combination of applied-mathematics tools (optimization, dynamical-system analysis) as well as ideas from physics, biology, mathematics and computer science. Anthrodynamics could be considered a branch of mathematical sciences, which may have the potential to shape health-care systems of the third millennium — compare the scope of 'anthrodynamics' with 'astrodynamics', a well-established discipline of mathematics. Figure 3 lists different branches of mathematics, which emerged from anthromathematics; the challenges and the opportunities presented by the last two require further elaboration.

The techniques from 'astromathematics' (a branch of mathematics put forward by the author on October 8, 2012) could be combined with 'anthromathematics', *e. g.*, techniques of controlling both the position and the velocity in a satellitelaunch vehicle could be adapted to generate ‘Growth-and-Obesity Vector-Roadmaps’ of children (Kamal *et al.*, 2016*a*, *b*) by matching slopes as well as values in the height- and mass-percentile trajectories — dynamical-system approach (Kamal, 2015*e*). 3-D movements of gymnasts may be analyzed by adapting mathematical framework used in the telemetry techniques for tracking rocket maneuvers (astromathematics) as well as robotic-arm control (control theory). The author proposed a new branch of mathematics ‘astro-anthromathematics’ recently, which should combine the strengths of astromathematics and anthromathematics (Kamal, 2015*c*).

Taking up ideas from control engineering, physics, astrodynamics, mathematics, computer science and information technology to interface them with human biology may open up new venues of research and engineering applications. Such a body of knowledge could be termed as ‘astro-anthrodynamics’.

Research, Teaching and Community Outreach

Teaching programs, like ‘Program of Sport and Anthromathematics’, without input from research faculty, working on indigenous problems, and without output trickled down to serve the community, they are part of, may be visualized as a tree stem (teaching) without roots (research) and without branches carrying leaves (community outreach). Figure 4 gives the hierarchy of research, teaching and community outreach (Kamal, 2015*f*). A program of studies should get its lifeline blood from research carried out to solve indigenous problems. The program should have deep roots in the community, which supports it through human resources (bright students), financial resources (funding) and emotional resources (goodwill and encouragement). The Early-Talent-Research-Participation Program, conducted by the author during 2002-2010, is an example of such community-outreach activity.

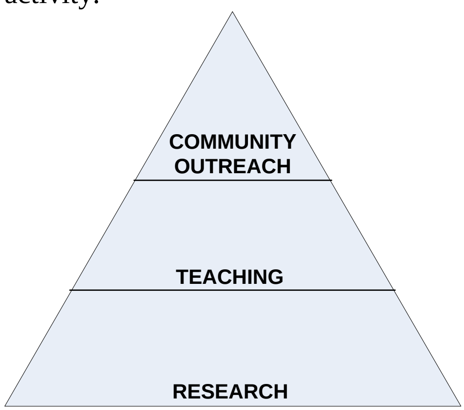

Fig. 4. The hierarchy of research, teaching and community outreach — first appeared in Kamal (2015*f*)

MSc **Sport Mathematics** Key Courses *Sport Kinesiology* (2 + 1) *Sport Biomechanics* (2 + 1) *Anthrotopolgy & Gymnastic-Performance Analysis* (2 + 1) *Fluid Dynamics & Exercise Physiology* (2 + 1)	*MSc* **Anthromathematics** Key Courses *Anthromathematics* (2 + 1) *Mathematical Statistics* (2 + 1) *Algebraic Topology & Orthopedics* (2 + 1) *Fluid Dynamics & Blood-Flow Modeling* (2 + 1)
MPhil **Sport and Anthromathematics** Key Courses *Research Methodology for Sport & Anthromathematics* (2 + 1) *Advanced Anthromathematics* (2 + 1) *Advanced Sport Mathematics* (2 + 1)	*PhD* **Sport and Anthromathematics** Key Courses *Independent Study in Sport & Anthromathematics* (0 + 3) *Topics in Anthromathematics* (2 + 1) *Topics in Sport Mathematics* (2 + 1)

Fig. 5. Key courses offered in 'Program of Sport and Anthromathematics'; students coming from mathematics have to complete non-credit foundation course in physical education and sport sciences and vice versa — details given in Kamal (2015*d*)

Objectives of 'Program of Sport and Anthromathematics'

'Program of Sport and Anthromathematics' has been described in an earlier paper published in the same journal (Kamal, 2015*d*). This program has been developed after considering mathematics research, teaching and community outreach challenges and opportunities (Kamal, 2004; 2005*a*), in line with the guidelines for mathematics programs prepared by Higher Education Commission, Government of Pakistan (Kamal, 2005*b*; 2008*b*) as well as suggestions given by other mathematician-educationists (Holton, 2001; Sriraman & English, 2010). Highlights are shown in Figure 5. The main objectives of Program of Sport and Anthromathematics are listed below**:**

- To instill habits of creative thinking, critical analysis (Kamal & Siddiqui, 1986) and rigorousness, combined with the entertainment aspect of sport sciences so that enrolled students start enjoying sport and anthromathematics
- To make the student appreciate the uniqueness of mathematics (symbolism related to quantity and space) as the language of all sciences, the tool

of the tools, having the power of generalization and the power of application — a subject, which transcends cultural, ethnic, national and religious boundaries

- To develop ability in students to formulate a problem by developing solid and correct concepts using the language of mathematics by training the incumbent to think and to reason with precision (Kamal, 2003; Kamal *et al.*, 2009)
- To equip students with the tools required and the mathematical techniques applied in the sport industry and the health-care organizations (Kamal, 2008*c*)
- To propose mathematical solutions to indigenous problems arising in the sport industry and the health-care sector (Kamal, 2008*e*)
- To motivate and to empower the students so that they can become leader-integrators of sport-and-anthromathematics community (Kamal, 2013*d*)

The following quote from one of my students shows the process of empowerment**:**

"You urged me to try, when I gave up ….
You encouraged me, when I attempted ….
You instructed me, when I progressed ….
You appreciated me, when I achieved ….
Dear Sir, you have helped me in every way."
(Hassan Jalees, MSc, Mathematics, University of Karachi, Class of 2003)

Components of 'Program of Sport and Anthromathematics'

The plan of studies has 3 components — formal teaching, examinations and projects (Figure 6). These three should be integrated in such a way that each one

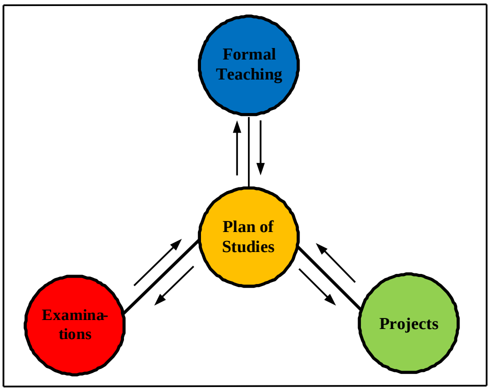

Fig. 6. The three ingredients of plan of studies of 'Program of Sport and Anthromathematics'

reinforces the other two. Formal teaching should prepare the student to do well in the examinations and complete the assigned project during the summer term.

Topics taught in ‘Program of Sport and Anthromathemmatics’ should include recently added body-of-knowledge, some of which should be from research conducted in laboratories associated with the program. **Additional File 1** (http://www.ngds-ku.org/Papers/J44/Additional_File_1.pdf) contains sample course plan and course outline**.**

In order that a professor can conduct the assigned course properly as well as find some time for research and administrative duties, human assistance should be available in the form of**:**

- dedicated secretary/office assistant for each course to take care of paper-work
- 4 teaching assistants, one each to**:**

i) conduct discussion and problem-solving sessions
ii) conduct and grade quizzes, hourlies and final examinations
iii) conduct laboratory sessions, grade laboratory reports and arrange laboratory final examinations
iv) work with students to help them complete research proposals and projects

The breakdown of grades (marks) should be as under**:**

Hourlies (best 2 out of 3 counted; each hourly has 20% weightage)	40%
Quizzes (best 5 out of 8 counted; each quiz has 4% weightage)	20%
Final Examination (separate passing head)	40%
Total	**100%**

Formal Teaching

Formal teaching is the core activity of the program. Efficiency (conduct of classes according to schedule, coverage of all topics, course outline and course breakdown into date-wise lecture-topics) and effectiveness (students understanding course contents, becoming motivated and transforming into knowledgeable citizens) are the basic requirements. The average students learn most of the topics, the weakest students are brought into the mainstream and the over-smart students are envisioned, at the same time their questions are dealt in such a manner that the classroom kinematics and dynamics are not disturbed (Kamal, 2016). To keep the students attentive and make them interact with fellows other than their own friend-groups as well as break mischief-making groups, it was suggested to shuffle students once during a session (Kamal, 2015*f*).

Another way to generate enthusiasm among students is ‘hands-on training’, through carefully-designed lab work**:**

"*Tell me*, and I'll forget….
Show me, and I may not remember….
***Involve me*, and I'll understand….**"
(Native American Quote)

The number (2 + 1) after a course title in Figure 5 indicates that 2 credit hours are reserved for theory (lectures, discussion and problem-solving sessions), whereas one hour is for laboratory. There should be enough functioning-equipment sets so that not more than 2 students perform on a set. The experiments should correspond to the topics covered in theory classes. In addition, they should, not only, consist of mere collection of data, calculations and computation of results, but also, encourage the student to think deeply so that the future researcher should investigate underlying causes and effects, to understand the true spirit and the purpose of experimentation (Kamal, 2007). The great scientific experiments serve to develop the content of a theory (decompose a simple phenomenon, demonstrate underlying unity within apparent variety, find hidden mechanism of a known effect, provide existence evidence), elaborate the formal aspects of method (decide between rival hypotheses, exploit an accident, explore the characteristics of a naturally-occurring process, find the form of a law, inductively, interpret null results, use models to simulate processes) and establish techniques (determine accuracy and care in manipulation, show power and versatility of apparatus). Some thought-provoking experiments may be designed on the following lines (Kamal, 2009)**:**

- Study of variation of intensity with distance from multiple sources (point, line, laser) using photocell
- Appearance (disappearance) of Newton's rings if plano-convex lens is moved away (towards) the sodium light source (study of fringe movement using edge-based algorithm to be included for advanced undergraduate laboratory)
- Height and curvature maps of solid objects (cylinders, spheres, cones, wedges) using moiré fringe topography and rasterstereography (edge-based moiré and edge-based raster to quantify infinitesimal movements might be suitable for graduate laboratory)

The teaching assistant assigned to a laboratory course should run experiment on each apparatus at the start of a given semester to make sure that all sets are performing properly. In addition to grades of each report, teaching assistant should record results of experiment quoted by each group. At the end of the semester, the assistant shall have accumulated 10 or more results performed by different groups on each set. These could be examined to determine equipment performance during the semester.

Although, the classes end and the students are given preparatory leave a few days ahead of start of examination period, the author has continued the practice of maintaining 2 dedicated hours for the last-minute guidance session (attendance optional) 2-*days* before the scheduled examination of that particular course. The rationale is that the students start studying the subject matter as the examination date approaches. The problems then pile up, which need to be discussed with the instructor. In the guidance session key concepts may be revised and students' problems addressed.

Problem-solving approach is emphasized during the study sessions. Problem solving in the classroom (Kamal, 2008*c*) prepares the student to set-up problems, which could be taken up in laboratory (Kamal, 2007) and eventually field-tested and implemented as an industrial product (Kamal, 2008*e*). Classroom problem solving should consist of 2 sets — the first set should consist of problems to be solved on board by teaching assistant; the second set should be homework problems, which are turned in and graded (solutions put in the seminar library). At the start of course, the instructor should take a pre-test (non-credit) so as to know deficient areas of each student to work on during the term. The course should start with revision of key concepts, at the end of every lecture session, the instructor should ask some students to give one-*minute* summary of lecture, the last one-*minute* summary to be presented by the lecturer. The next lecture should start with a one-*minute* summary of last lecture as well as learning objectives of current lecture. Two lecture sessions should be followed up by one discussion session (no new concepts or techniques taught, but the already covered ones presented in a different manner with fresh examples) and one problem-solving session. There should be a review session arranged before each hourly and before the final examination, covering key concepts, techniques and derivations (theoretical portion) as well as solution of a new problem-set (specially prepared for review session). In addition, during the final-exam-review session there should be discussion about the science and the art of paper solving as well as solution of past papers.

The goal is to prepare the students to solve unseen problems in the examination (the ones not solved in problem-solving session, homework or review session). At the end of the course, the instructor should administer a post-test (non-credit), covering the same ideas, concepts and techniques, tested in the pre-test (but not the same questions, so that memorizing questions and their solutions should not help) to find out effectiveness of delivery of material. In the words of Prof. Dr. Sheldon Rottenberg of SUNY Downstate Medical Center, "A best teacher is not the one, who *knows* most, but the one, who *gives* most."

Examinations

The purpose of examinations is to test the ability of student to digest contents with sufficient depth and breadth so that the incumbent becomes capable to understand significance of taught discipline and relationship with other disciplines. The quality of examinations determines the quality of a teaching program, as this is a direct measure of knowing how well are contents delivered to students. The main challenges in the construction and the conduct of examinations may be summarized as**:**

- Examinations should be constructed in such a way that an average student should be able to solve the entire paper in 80% of the allotted time, leaving the rest of 20% for revision. The author adapted the strategy to, himself, solve the paper, note down the time spent in solving each question, total this time and give the students 3 times the amount of time he spent to solve the entire paper, realizing that instructor is an expert of the subject, whereas the student is trying to comprehend and digest the subject matter.
- 50% of the paper should be so easy that an average student should be able to solve it easily. 25% of the paper should be for the above-average student and the final 25% of paper should be for the smart student. The over-smart student may, still, do something unusual, like solving the entire paper in half the allotted time and developing a new model/working on a new line of calculation during the rest of time. To cite an example, the main calculations of (Kamal & Husain, 1978; 1988) were done during the final examination of MSc (Final) Course, Lattice Dynamics.
- If the paper is easy, grading should be strict; if the paper is hard, grading should be lenient. Ideally, grading distribution should be a bell-shaped curve, indicative of a balanced paper. In case, it is skewed to the left (paper hard/checking strict) or to the right (paper easy/checking generous), a scaling of grades should be done to convert the distribution to a bell-shaped curve.
- To curb cheating/use of unfair means during the examination, the following measures are suggested**:**

a) Arrangement of a sufficient number of invigilators, who are experienced and dedicated to duty

b) Honor-statement to copied from paper and signed by the examinee, which states, ‘My signatures, below, testify that I am the person, whose name and photograph appear on the Admit Card. Upon my honor, I declare that the following work is my own, completed without giving or receiving unacknowledged help, without copying, or the use of any unfair means.’

c) No borrowing or lending by students of pen, pencil or any other item, in particular, calculators (must bear easily-visible name)

d) Seating layout during the conduct of examination recorded
e) Multiple-format papers, even for subjective portion (papers are mixed in such a way that ‘A’, ‘B’, ‘C’ and ‘D’ formats appear, one after the other, so that a student sitting behind receives a different format from the one sitting in front)

University-of-Karachi Examinations
In order to make the students start and finish at the same time, the front side of question paper contains only paper format, instructions, time-chart layout and honor-statement. Students are distributed answer books and paper facing the front side 10-*minute* ahead of start time. There is a format column on the upper-right-hand corner of the answer book, which has to be filed out by the student according to the distributed paper. The student has to do 3 more things. On the front page of the answer book, draw layout of the time chart, copy honor statement and sign the statement. Filled-out time-chart and signed honor-statement each carries 2 marks. The timings entered by students in time-chart could, later, be processed using software to find out how much time each student took to solve a certain question. Ideally, this time distribution should be a bell-shaped curve, the mean of which should be 3 times the amount of time taken by the instructor to solve the same question.

As the clock ticks the announced time, the instructor starts stopwatch/countdown timer and announces ‘start now’. The students turn the paper and start solving the questions in the answer book. They are not allowed to write anything on the printed-paper, except their names on both sides, in order to prevent exchanging of paper. When the allotted time ends, the instructor announces ‘all pens down’. The students have to put the question papers inside their answer books and close them so that the top page faces them. A penalty is imposed on any student working after this announcement.

The answer books are (serial) numbered on the upper-left-hand side by the instructor, this number, also, appears on the yellow-attendance sheet as a serial number in a column added on the left side. The students are required to sign their attendance in the same row bearing the serial number. This serial number is, also, used to generate seating layout (to keep a permanent record of who is sitting behind whom, to assist in deciding the case of copying in case a match of text is found in the answer books). On the right side of the attendance sheet, another column is added showing the format of paper. At the end of examination, the answer books are turned in along with question paper (name matched on question paper and answer book) and a tick mark is made on a photocopy of the filled attendance sheet in front of the serial number (which is written on the upper-left-hand corner of the answer book). Hence, this real-time counting-system eliminates the need of post counting scripts. It can, also, pinpoint, in real time, any script, which is not turned in.

The examination paper (in PDF format) is uploaded on the author's homepage 12 hours after the examination ends. A PDF version of solution is prepared, which is shown on multimedia projector and discussed with the students during designated time slot. For part I of course, paper is solved in the first class of part II of course.

In the examinations conducted at University of Karachi, there is a restriction on the number of photocopies and laser printing, which could be done from institutional budget. Hence, the paper is designed in a compact form with only 2 pages covering the entire material. The front page consists of instructions, but have no examination questions. The back page contains all the questions. The answers are to be written in the supplied answer book separate from the question paper. The additional tasks are (by students) drawing time-chart, (by invigilators) the exercise of attendance matching, paper-name matching, (by grader) finding scores of all questions and transferring them to front panel to get the total score.

Additional File 2 (http://www.ngds-ku.org/Papers/J44/Additional_File_2.pdf) contains SOPs for Invigilators (instructions and seating arrangement), sample examination paper and its solution (for courses conducted at University of Karachi).

AKU (the Aga Khan University), IBA and SZABIST Examinations
For the examinations conducted at the above institutions, there is no restriction on photocopying. Hence, a more structured paper pattern is followed. Paper consists of 5 or 6 pages, with the front (and sometimes the last page) containing instructions. Questions are typed starting page 2, with a column on left-hand side to enter grade of each part. Question has to be solved in the allotted space and answer entered in the given box given on right-hand side so that the answer is easily visible to the grader. On the bottom of each page (one page contains only one question), there is a box to write down time spent in solving this question. Since the paper is photocopied only on one side, the backside of page (facing the printed question) may be used for rough work. There is a box at the bottom to enter sum of all marks on the same page. A total of all these entries in the bottom left generate total score, which is entered on the second page (score not entered on top page to protect privacy) along with tentative grade based on all hourlies (conducted at the end of each month), quizzes (conducted weekly) and assignments to date as well as total number of absents accumulated by the student till the announcement of this result. The schedule is arranged in such a way that tentative grade, after the first hourly, becomes available to student

before the deadline to withdraw from a course. This makes it possible for a poorly performing student to withdraw from the course instead of having a bad GPA reflecting on transcript. A compact solution of each hourly is prepared (usually 2 pages), a copy of which is attached at the end of graded paper. The students look at their solutions and discover their mistakes by looking at instructor's solution. Since, quiz consists of only one page, generally consisting of 2 questions, solution is written on the same page, photocopied and attached with the graded quiz. The students have to return all graded hourlies, quizzes and their solutions after looking at them.

In order that the students start at the same time in each hourly and the final examination, the test paper is handed over stapled at the bottom. Format is, already, written on the paper. The students write their names on the first page, write honor statement and sign it. At the signal, 'start now', they open the staple, write their names on top of each page and start working on the paper.

Additional File 3 (http://www.ngds-ku.org/Papers/J44/Additional_File_3.pdf) contains sample quiz, hourly and their solutions (for courses conducted at AKU, IBA and SZABIST).

Projects

Projects serve the purpose of training students to conduct small-scale research and present either as conference presentations or papers in 'Student Journal of Research'. Projects are conducted in groups of 4 or 5 students. During the first semester, the students select a research topic, conduct test runs/simulate, analyze the data and prepare a research proposal. Contribution of each member of group is, clearly, mentioned in the proposal. The students give a collective presentation to justify the work, attended by the instructor, respective teaching assistant and the fellow students. Each member of the group presents for 1 to 2 *minutes*. The presentation is videotaped and replayed. The first critique is by the presenter, the second one by the fellow students, the third one by the teaching assistant and the fourth one by the instructor (course supervisor).

An anthromathematics project requires collection of data on human subjects. The research proposal has to be approved by 'Institutional Review Board' and must conform to the ethical and the human-right standards applicable in the region (Kamal *et al.*, 2002; Kamal, 2006).

Research proposals should explore the anatomy of a research problem, which consists of answering 3 questions — why? what? and how?

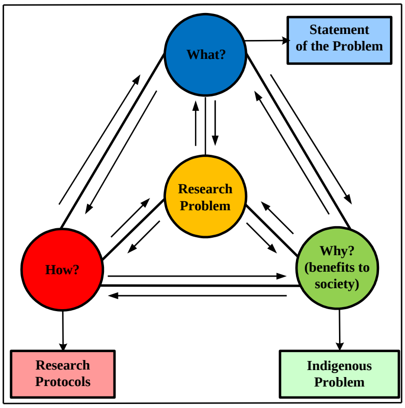

Fig. 7. The anatomy of an indigenous research problem — first appeared in Kamal (2015*f*)

These are explained below (Figure 7)**:**

- *Why to conduct a research project?*
  The answer should highlight significance of the problem at the same time elaborating benefits to society, in particular, the local community, which is supporting the research team.
- *What the research project is about?*
  A clear and a precise statement of problem after discussing the background of problem, which explains technical terms and definitions and, possibly, design of the study.
- *How to conduct a research project?*
  This gives research protocols, which include description of mathematical modeling involved, mechanism of data collection, data processing and analysis using mathematical-statistical techniques and softwares as well as expected results.

Additional File 4 (http://www.ngds-ku.org/Papers/J44/Additional_File_4.pdf) gives highlights of a research proposal and a sample template to prepare proposals.

During the summer semester the student groups conduct field study, collect and analyze data using mathematical-statistical techniques. During the second semester the groups finish writing their reports and present the completed projects. These presentations sometimes include live demonstrations of the techniques, which are critically analyzed using the same hierarchy adopted for research-proposal presentation.

SF-Growth-and-Imaging Laboratory is well equipped with equipments for anthro-

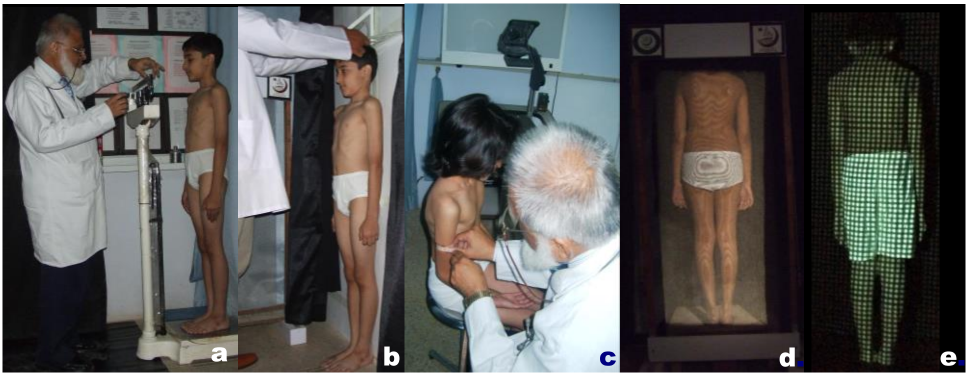

Fig. 8*a*-*e*. Measurement of height, mass and MUAC (mid-upper-arm circumference) in SF-Growth-and-Imaging Laboratory; moiré fringe topography and dotted-rasterstereography for detection of scoliosis — (*a*), (*b*) first appeared in Kamal & Jamil (2012); (*c*) in Kamal & Jamil (2014); (*d*, *e*) in Kamal *et al.* (2016*d*)

pometry, image recording and image processing, which could be used by students to complete their projects. Figures 8*a*-*e* provide a glimpse of some activities, which are conducted in this laboratory. Breakdown of marks for courses Project I and II is given in appendix. **Additional File 5** (http://www.ngds-ku.org/Papers/J44/Additional_File_5.pdf), lists projects completed by students of the anthromathematics group.

Additional Activities

Co-curricular activities, which broaden the scope of a degree program educating the community about the academic endeavor (a pre-requisite to generating funding from community) include debates on issues in sport and anthromathematics, editing and contribution in newsletters and arrangement of movie shows followed by popular lectures. Open houses and cyber science club (internet discussion forum for high-school students) may motivate the youngsters, who would be future enrollees in the program.

On a more serious note, participation and organization of weekly seminars (student seminars, colloquium and specialized seminars), participation and organization of conferences as well as publication of students' research journal develop students' soft skills. There should, also, be workshops for professional-skill development and short courses.

Pedagogical Opportunities and Challenges

Simple anthropometric measurements, like measurement of height, offer a wealth of pedagogical opportunities in biology, chemistry, engineering, health and safety,

Biology	The metabolism of food
Chemistry	The process of conversion of food resulting in *tissue synthesis* (the phenomenon of height gain)
Engineering	Level surface needed, mounting of engineering tape (vertical mounting checked by plumb line)
Health and Safety	Evaluating nutritional status, failure to gain height may be a signal to some physical problem (failure-to-grow); failure to gain height and achieve developmental milestones may indicate a much deeper problem (failure-to-thrive) — pediatrician should look for indications of abuse (neglect, peer pressure/bullying, verbal, physical, sexual) in this situation (Kamal, 2011*c*)
Mathematics	Significance of serial measurements, plotting of graph, computation of slope, time-series concept, prediction of adult height, comparison with cut-off height for armed-forces career
Physics	Techniques of measurements, achieving reproducibility, applying equal weight on both feet
Quranic Studies	The Holy Quran (sacred book of Muslims) mentions appointment of Tālōt as king over Israelites (verse 247, chapter 2, *Suratul-Baqara*). It is mentioned that Samuel (peace be upon him) had a rod. It was told to Israelites that their king would be as tall as the length of rod — comparison of height with agreed-upon standard (Khan and Naeemuddin, 1999)

Fig. 9. Pedagogical challenges and opportunities offered by the activity of measurement of height — first appeared in Kamal (2006)

mathematics, physics and Quranic studies (Figure 9). Height and mass are the most important parameters in diagnosing problems relating failure-to-grow and failure-to thrive (Kamal, 2006). It has been observed that care is not taken to record these measurements properly in many studies. Figures 10*a*-*c* show common mistakes in recording of mass. In some studies, students are not undressed for anthropometry, with the result that their proper postures and complete inhaling

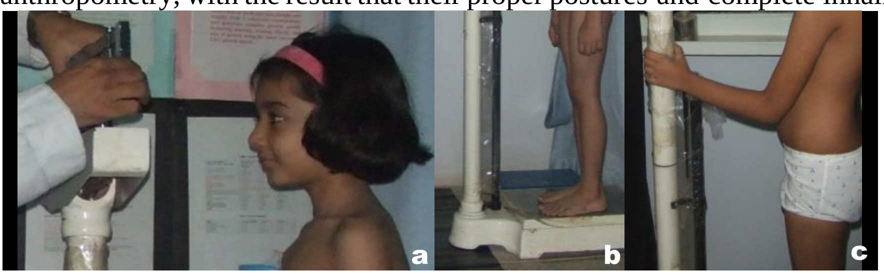

Fig. 10*a*-*c*. Common errors in measurement of mass — hair-band not removed; feet not positioned correctly and student holding on to beam scale — first appeared in Kamal *et al.*(2013*c*)

during the measurement process may not be checked (there is a slight difference in the values of heights and masses during complete inhaling and complete exhaling). The NGDS Team has been, constantly, improving least counts for measurements of heights and masses and insisting that students follow standard protocols during measurements of height, mass and MUAC (Kamal *et al.*, 2013*c*). Pedagogical opportunities generated by the activity of measurement of mass are listed in Figure 11.

The active and the inquiring minds of the students would pose pedagogical challenges provided opportunities to think, to explore, to question and to reason are provided (Kamal & Siddiqui, 1986). Below are given some ideas to enhance height- and mass-measurement techniques, reproduced from Kamal *et al.* (2016*a*), a food for thought for the over-smart mind (Kamal, 2016)**:**

- Use of circular scale (just like in micrometer screw gauge) instead of Vernier scale to reduce least count of height scale from 0.005 *cm*, *i. e.*, 0.05 *mm* (Kamal *et al*., 2016*b*) to 0.001 *cm*, *i. e.*, 0.01 *mm* — similar procedure to reduce least count of beam scale from 0.005 *kg* , *i. e.*, 5 *g* (Kamal *et al*., 2016*b*) to 0.001 *kg*, *i. e.*, 1 *g*, the constraint being the matching of mass of circular scale with mass of the sliding weight
- Wheatstone-bridge-type system to ensure equal weight exertion on both feet for measurement of height as well as mass

Biology	The metabolism of food
Chemistry	The process of food conversion resulting in gaining energy, sweating
Engineering	Need of level surface, checking if the weighing machine, itself, is level
Health and Safety	Rapid loss of weight signals physical problems, unutilized food results in fat deposit, contributing to obesity
Mathematics	Significance of serial measurements, plotting of graph, computation of slope, concept of time series, prediction of adult mass (weight), net-mass computation from gross mass (Kamal, 2010), optimal mass-for-height — net mass is defined as mass with zero clothing on, gross mass is the mass recorded in indoor clothes
Physics	Measurement techniques, reproducibility of measurers, exertion of equal weight on both feet
Quranic Studies	Maintaining optimal weight-for-height is encouraged in the Holy Quran (verse 29, chapter 17, *Surah Bani-Israel* or *Suratul-Asra*) by stating that one should exercise discretion in spending, neither to spend too much like burning candles at both ends nor become stingy (Kamal and Jamil, 2012)

Fig. 11. Pedagogical challenges and opportunities offered by the activity of measurement of mass (weight) — first appeared in Kamal (2006)

Biology	The metabolism of food
Chemistry	The process of food conversion resulting in proper muscle and fat development
Engineering	Need of level surface, checking if the stool, itself, is level
Health and Safety	Evaluating nutritional status (Shakir strip has red and green regions indicating normal and at-risk conditions, both on the lower and the higher side), inequality in MUAC may be indication of trunk deformity, in particular, scoliosis (an improper exercise routine may, also, result in asymmetric muscle development)
Mathematics	Measurement of circumference, midpoint of distance between acromial and radial landmarks, significant difference between right and left arm as threshold of trunk-deformity risk, calibration — conversion of MUAC taken on clothing to that taken on body (Kamal, 1986; Kamal *et al.*, 2011*c*)
Physics	Measurement techniques, reproducibility of measurers, exertion of optimal pressure on arm, use of a mirror or camera/monitor to visualize opposite side of hand in order to make sure tailor's tape is horizontal
Quranic Studies	Measurement of right MUAC should precede left MUAC. According to the Holy Quran, men who receive their deed record in right hand are successful and those who receive it in their left hand are doomed (verse 19-37, chapter 69, *Suratul-Haaqa*)

Fig. 12. Pedagogical challenges and opportunities offered by the activity of measurement of MUAC — first appeared in Kamal (2006)

- Symmetric moiré (Figure 8*d*) of back (about the sagittal plane) during mass recording to ascertain proper posture
- Symmetric moiré of front (about the sagittal plane) during height measurement to make certain upright posture

Pedagogical opportunities presented by the activity of measurement of MUAC are listed in Figure 12.

Conclusion

Mathematics is the unique discipline, which has the power of generalization and the power of application. Result in one dimension may be generalized to *n* dimensions. A mathematician develops the power to visualize abstract concepts. The distinction of mathematics to bring rigor to proofs and exactness to calculations makes it tool of the tools. The teaching of a concept in physical mathematics should include rigorous proof, physical interpretation and application. For example, proof using $\in_{ijk}$ notation of vanishing of curl of a gradient of potential should be followed by interpretation of curl as rotation at a point and gradient as maximum rate of change between two equipotential surfaces. Applications may include definitions of electric potential and gravitational potential. The student should be trained to link concepts in different scenarios, *e. g.*, fast freeze in structural biology and in fertilizer production (similarity of processes) as well as electrical and gravitational potentials (similarity in mathematical expressions). The approach of a mathematician differs from the approach of a physicist — conservative forces are recognized by a mathematician as having no functional dependence on velocities or higher derivatives (such forces are functions, solely, of coördinates), whereas a physicist would consider work done around a closed path to be vanishing. A mathematical equation gives clues to the underlying physics, whereas physics guides the form of the resulting mathematical equation (appearance of tensor in an equation suggests system anisotropy and vice versa).

Anthromathematics combines the beauty of mathematics with the versatility of a living human body. An example is solution of problem of electrical-signal transmission in the human brain (neuron-synaptic system), which involved 10^{32} entries by solving a $10^{16} \times 10^{16}$ matrix. The process generated a mathematical definition of brain death. The problem was solved using the rigor of mathematics at a time (1987-1990), when the fastest supercomputer of the world existing (Cray XL III at the Los Alamos Laboratories) could not even store entries of this matrix. For those, who do not want to get involved in such a sophisticated mathematical endeavor, 1st to 4th generations solutions of childhood-obesity problem are available, the computations involve only linear and box interpolation (using only two-point form of straight-line equation). For still those, who want to work with equipments, there is a task to enhance height and mass scales.

The Holy Quran has emphasized two topics in detail, our universe and our self — the two extremes dealing with the largest distances (measured in *parsec*) and the smallest distances (measured in *microns*). Creation of the universe is studied in cosmology, The heavens and the earth are taken up in astronomy. Motion of planets is explored in astromathematics and astrodynamics. The human body is deliberated upon in anthomathematics and anthrodynamics. The author had a chance to study and to work in the areas of cosmology, astronomy and astrodynamics. IN the near past, it was suggested to combine ideas from astrnomathematics and anthro-mathematics to bring out a new field, astro-anthromathematics. While this may be a step forward, combining the strength from physics, control theory and dynamical-system analysis should have the potential to reach out from the tiny DNA to the vastness of the cosmos through astro-anthrodynamics, which may provide answers to the question of existence of life on other planets, in other galaxies or alien life-form, at the same time improving the quality of life for us mortals. This would be the true spirit to subdue whatever is in the heavens and the earth, as enjoined by *Allah Subhahahu wa Taǎla* in the Holy Quran.

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Appendix

Breakdown of grades (marks) for the courses Project I and II are given below**:**

Proposal/Project§ (60%) + Journal Club¶ (20%) + Guest Seminars$ (20%) = 100%

§oral presentation 10% + poster presentation 10% + written report 40%
¶critical review of a paper — oral presentation 10% + written report 10%
$intelligent questions/comments 10% + one-page critique of each seminar 10% — abstract of talk + e-mail address of speaker provided a week ahead of scheduled presentation

References

1. De Mestre, N. (1990). *The Mathematics of Projectiles in Sport*. Australian Mathematical Society Lecture Series 6, Cambridge University Press, Cambridge, UK
2. Geng, Z. J., D. Tunnell & P. Gao (2009, September 28). Method and system for a three-dimensional facial-recognition system, *US Patent No*. 7804997 B2, assignee**:** Technest Holdings, Boston, Massachusetts, United States
3. Haigh, J. (2009). Uses and limitations of mathematics in sport. *IMA Journal of Management Mathematics* **20 (2):** 97-108
4. Holton, D. (2001). *The Teaching and Learning of Mathematics at the University Level***:** *An ICMI Study*. Kulwer Academic, New York (editor)
5. Hopper, C. (1984). Knowledge — Toward an integration. *Journal of Physical Education, Recreation and Dance* **55 (3):** 66-68 (points of view)
6. Jenkins, D. (2008). Anthropology, mathematics kinship**:** A tribute to the anthropologist Per Hage and his work with the mathematician Frank Harary. *Mathematical Anthropolgy and Cultural theory***:** *An International Journal* **2 (3):** 1-22 (July 2008)
7. Kamal, S. A. (1982*a*). Measurement of angle of spinal curvature by moiré topographs. *Journal of Islamic Medical Association (United States)* **14 (4):** 145-149, full text**:** http://www.ngds-ku.org/Papers/J04.pdf
8. Kamal, S. A. (1982*b*, March 8-12). Moiré fringe topography for measurement of angle of spinal curvature in three dimensions. *March Meeting of the American Physical Society*, Dallas, Texas, United States (poster presentation); *Bulletin of the*

American Physical Society **27 (3):** 301, abstract#GY15**:** http://www.ngds-ku.org/pub/confabst1.htm#C16:

9. Kamal, S. A. (1986). Relationship of anthropometric measurements taken on clothing to those taken on body. *Karachi University Journal of Science* **14 (1&2):** 35-39, full text**:** http://www.ngds-ku.org/Papers/J05.pdf
10. Kamal, S. A. (1992, June 25-July 9). Modeling of heart function. *The Seventeenth International Nathiagali College on Physics and Contemporary Needs*, Nathiagali, KP, Pakistan, pp. 22, 23, abstract#16**:** http://www.ngds-ku.org/pub/confabst0.htm#C38:
11. Kamal, S. A. (1996*a*). A 3-D-static model of the human spinal column. *Karachi University Journal of Science* **24 (1):** 29-34, full text**:** http://www.ngds-ku.org/Papers/J18.pdf
12. Kamal, S. A. (1996*b*). Combination of moiré contours and edge-based algorithm to study motion in the sagittal plane. *Karachi University Journal of Science* **24 (2):** 53-60, full text**:** http://www.ngds-ku.org/Papers/J17.pdf
13. Kamal, S. A. (1996*c*, June 27-July 11). 3-D-dynamic modeling of the human spinal column. *The Twenty-First International Nathiagali Summer College on Physics and Contemporary Needs*, Nathiagali, KP, Pakistan (poster presentation), abstract**:** http://www.ngds-ku.org/pub/confabst0.htm#C42:
14. Kamal, S. A. (2003, February 7-9). The training of a physicist**:** From concept building to problem-solving skills. *The Second International Conference on Physics Education*, Center of Physics Education, National Center for Physics and Department of Physics, University of Karachi, Karachi, Pakistan, full text**:** http://www.ngds-ku.org/Papers/C57.pdf
15. Kamal, S. A. (2004, December 4, 5). Mathematics research and teaching in University of Karachi**:** Challenges and opportunities. *The Winter Conference in Mathematics*, Center for Advanced Studies in Mathematics, LUMS (Lahore University of Management Sciences), Lahore, Pakistan, p. 18, abstract#24**:** http://www.ngds-ku.org/pub/confabst.htm#C62:
16. Kamal, S. A. (2005*a*, April 30). Mathematics research, teaching and community outreach in University of Karachi**:** Challenges and opportunities. *Informative Mathematical Event*, Karachi Mathematical Association and Department of Mathematics, University of Karachi, Karachi, Pakistan, abstract**:** http://www.ngds-ku.org/pub/confabst.htm#C63:
17. Kamal, S. A. (2005*b*). *Curriculum of Mathematics (Revised)*. Higher Education Commission, Islamabad, Pakistan (editor), full text**:** http://www.ngds-ku.org/HEC/math-booklet-final-2005.pdf
18. Kamal, S. A. (2006, May 23). *Manual for Obtaining Anthropometric Measurements.* The-NGDS-Pilot-Project-e-Publication, University of Karachi, Karachi, Pakistan, pp. 11, 12, full text (version 9.11; release date**:** April 7, 2016)**:** http://www.ngds-ku.org/ngds_folder/M02.pdf
19. Kamal, S. A. (2007). Observations and experiments in science. *AAGAHI (Magazine of Government Degree College for Women, Azizabad, Karachi, Pakistan)*, pp. 1-3 (intellectual preview), full text**:** http://www.ngds-ku.org/Articles/A19.pdf
20. Kamal, S. A. (2008*a*, April 23, 24). Pattern recognition using moiré fringe topo-

graphy and rasterstereography. *Proceedings of the International Symposium on Biometrics and Security Technologies (IEEE ISBAST 2008)*, Bahria University, Islamabad, Pakistan, pp. 1-7, full text**:** http://www.ngds-ku.org/Papers/C68.pdf

21. Kamal, S. A. (2008*b*). *Curriculum of Mathematics (BS 4-Year)*. Higher Education Commission, Islamabad, Pakistan (editor), full text**:** http://www.ngds-ku.org/ HEC/math-booklet-final-2008.pdf
22. Kamal, S. A. (2008*c*, December 18-20). From mathematics to technology**:** A bridge through physics and engineering. *Proceedings of the International Conference on Physics and the World of Today*, edited by M. A. Jafri and S. M. Naqvi, Department of Physics, University of Karachi, Karachi, Pakistan, pp. 32-39, full text**:** http://www.ngds-ku.org/Papers/C70.pdf
23. Kamal, S. A. (2008*d*, December 20-23). Role of mathematics in sports sciences and technologies. *The Thirty-Fifth All Pakistan Science Conference (Genomics for Health and Prosperity)*, University of Karachi, Karachi, Pakistan, p. 75; *Karachi University Journal of Science* **36 (1&2):** 5, abstract#72**:** http://www.ngds-ku.org/Presentations/Sports.pdf
24. Kamal, S. A. (2008*e*). Handling industrial projects. *RAWISH (Magazine of Government Degree College, Malir Cantonment, Karachi, Pakistan)*, pp. 47-49, full text**:** http://www.ngds-ku.org/Articles/A20.pdf
25. Kamal, S. A. (2009, December 16, 17). Mathematics of experimentation. *The National Conference on Physics and the World of Today*, Department of Physics, University of Karachi, Karachi, Pakistan, pp. 9, 10 (Prof. Dr. Muhammed Rafi and Prof. Dr. Muhammed Razi Hussain memorial lecture), abstract#1**:** http://www.ngds-ku.org/Presentations/Physics2.pdf
26. Kamal, S. A. (2010, March 22). Mathematics in the life sciences. *The National Conference on Mathematical Sciences (CMS 2010)*, Department of Mathematics, University of Karachi, Karachi, Pakistan, p. 19 (the Syed Firdous memorial lecture), abstract#10**:** http://www.ngds-ku.org/Presentations/Firdous.pdf
27. Kamal S. A. (2011*a*, February 19). From anthropometry to anthro-mathematics. Faculty of Medicine, the Ziauddin University, Karachi, Pakistan (research seminar)**,** abstract**:** http://www.ngds-ku.org/Presentations/Ziauddin.pdf
28. Kamal, S. A. (2011*b*, May 9, 10). Anthromathematics**:** A new branch of mathematics. *The Sixth Symposium on Computational complexities, Innovations and Solutions (CCIS 2011),* COMSATS Institute of Information Technology, Abbotabad, KP, Pakistan, pp. 13, 14 (keynote lecture), abstract#1**:** http://www.ngds-ku.org/Presentations/Anthromath.pdf
29. Kamal, S. A. (2011*c*, October 22). Curbing corruption in pre-university education. *Seminar on Curbing Corruption in the Education Sector*, the Education Committee, Transparency International Pakistan, Ambassador III, Hotel Marriott, Karachi, Pakistan, p. 1, abstract**:** http://www.ngds-ku.org/Presentations/TIP.pdf
30. Kamal S. A. (2013*a*, April 10). Anthromathematics**:** Mathematics of the third millennium. Department of Mathematics, FUUAST, Karachi, Pakistan (research seminar)**,** abstract**:** http://www.ngds-ku.org/Presentations/AMTM.pdf
31. Kamal, S. A. (2013*b*, September 4, 5). 3-D-spinal-column-surface analysis (height and curvature maps) by combining moiré fringe topography and rastereography

with backscatter-X-ray-scanning technology. *The First Undergraduate National Computing Conference*, Usman Institute of Technology, Karachi, Pakistan (keynote lecture), abstract**:** http://www.ngds-ku.org/Presentations/Backscatter.pdf

32. Kamal, S. A. (2013*c*, September 4, 5). From simple X rays to bone scanning using backscatter-X rays**:** A journey of 113 years. *The First Conference on Anthromathematics in the Memory of (Late) Syed Firdous (ANTHROMATHEMATICS 2013)*, Department of Mathematics, University of Karachi, Karachi, Pakistan and Government College, Hyderabad, Pakistan, p. 22 (the Syed Firdous memorial lecture), abstract#Anthro13-16**:** http://www.ngds-ku.org/Presentations/Scan.pdf
33. Kamal, S. A. (2013*d*, December 12). Designing curricula, which produce leader-integrator of tomorrow. *The Karachi University Educational Conference,* Faculty of Education, University of Karachi, Karachi, Pakistan, pp. 3, 4 (keynote lecture), abstract**:** http://www.ngds-ku.org/Presentations/Leader-Integrator.pdf
34. Kamal, S. A. (2014*a*, March 20). The challenges of anthroimaging. *The Second Conference on Mathematical Sciences (CMS 2014)*, Department of Mathematics, University of Karachi, Karachi, Pakistan, p. 2 (Prof. Dr. Iqbal Ahmed Khan memorial lecture), abstract#CMS14-02**:** http://www.ngds-ku.org/Presentations/Anthroimaging.pdf
35. Kamal S. A. (2014*b*, May 17). Sports and anthromathematics. *The Fifty-Fifth Annual Prize Distribution Function*, Government College, Hyderabad, Pakistan (seminar)**,** abstract**:** http://www.ngds-ku.org/Presentations/Sport_Mathematics.pdf
36. Kamal, S. A. (2015*a*). Acute malnutrition in a child suffering from cardiac problems. *International Journal of Biology and Biotechnology* **12 (4):** 585-600, full text**:** http://www.ngds-ku.org/Papers/J40.pdf
37. Kamal, S. A. (2015*b*). Anthromathematics**:** A new branch of mathematics. *RIVAYAT* (*Magazine of Government College for Men, Nazimabad, Karachi)*, pp. 10-13, full text**:** http://www.ngds-ku.org/Articles/A27.pdf
38. Kamal, S. A. (2015*c*, December 28-30). US-Childhood-Obesity problem**:** Solutions proposed in Pakistan. *The First International Conference on Life Sciences (Emerging Trends in Biological Sciences and Genomics)*, M. A. H. Qadri Biological Research Center, University of Karachi, Karachi, Pakistan, pp. 8, 9 (invited lecture), abstract**:** http://www.ngds-ku.org/Presentations/Childhood-Obesity.pdf
39. Kamal, S. A. (2015*d*). Designing curricula of mathematics, which produce leader-integrator of tomorrow. *Journal of Education and Research,* **3:** 11-42, full text**:** http://www.ngds-ku.org/Papers/J39.pdf
40. Kamal, S. A. (2015*e*). Optimal-mass management in obese children. *International Journal of Biology and Biotechnology* **12 (3):** 381-391, full text**:** http://www.ngds-ku.org/Papers/J38.pdf
41. Kamal, S. A. (2015*f*, September 2). Research empowering teaching for community development**:** An example from sport-mathematics research. *The Karachi University Second Educational Conference (Educational Issues in the Twenty-First Century)*, Faculty of Education, University of Karachi, Karachi, Pakistan, p. 1 (keynote lecture), abstract**:** http://www.ngds-ku.org/Presentations/Research-Teaching-ComDev.pdf
42. Kamal, S. A. (2016, February 12). Strategies to handle over-smart students in class.

The Karachi University Third Educational Conference (Education and Research), Faculty of Education, University of Karachi, Karachi, Pakistan, p. 1 (keynote lecture in honor of Prof. Muhammed Idrees Khan), abstract**:** http://www.ngds-ku.org/Presentations/Over-Smart.pdf

43. Kamal, S. A., A. A. Naz & S. A. Ansari (2016*a*). Growth-and-Obesity Vector-Roadmaps of the Pakistani children. *International Journal of Biology and Biotechnology* **13 (4):** 651-671, full text**:** http://www.ngds-ku.org/Papers/J43.pdf
44. Kamal, S. A., A. A. Naz, S. Musafar & S. A. Ansari (2016*b*, February 12, 13). Growth-and-Obesity Vector-Roadmaps generated using enhanced anthropometric instruments**:** The fourth-generation solution of childhood obesity. *The Karachi Physics Society First National Conference on Multi-disciplinary Topics in Physics*, Department of Physics, University of Karachi, Karachi, Pakistan, p. 56 (concluding talk), abstract#IT-04**:** http://www.ngds-ku.org/Presentations/Vector.pdf
45. Kamal, S. A., A. S. Choudhry & Y. A. Siddiqi (1996). Gait analysis using moiré fringe topography and rasterstereography (simultaneous recording). *Karachi University Journal of Science* **24 (2):** 7-18, full text**:** http://www.ngds-ku.org/Papers/J16.pdf
46. Kamal, S. A. & K. A. Siddqui (1986, December 27, 28). How to develop creative thinking and critical analysis? *Proceedings of the Second Workshop on Teaching of Physics*, edited by A. F. Hasnain, Karachi, Pakistan, pp. 51-56, full text**:** http://www.ngds-ku.org/Papers/C24.pdf
47. Kamal, S. A. & K. A. Siddiqui (1997). Covariant-generalized-coupling model of global-electrocortical activity. *Karachi University Journal of Science* **25 (1):** 29-39, full text**:** http://www.ngds-ku.org/Papers/J19.pdf
48. Kamal, S. A. & K. A. Siddiqui (2002). The human heart as a system of standing waves. *Karachi University Journal of Science* **30 (1&2):** 55-63, full text**:** http://www.ngds-ku.org/Papers/J25.pdf
49. Kamal, S. A., K. A. Siddiqui and Naseeruddin (2009). Concept building in the undergraduate mathematics and physics curricula. *Karachi University Journal of Science,* **37 (1&2):** 1-6, full text**:** http://www.ngds-ku.org/Papers/J28.pdf
50. Kamal, S. A., K. A. Siddiqui & S. A. Husain (1989). Spacetime representation of global-electrocortical activity. *Biological Cybernetics* **60 (4):** 307-309, full text**:** http://www.ngds-ku.org/Papers/J08.pdf
51. Kamal, S. A., K. A. Siddiqui, S. A. Husain, M. Naeem & N. U. Khan (1992). Effects of weak electromagnetic fields on global-electrocortical activity. *Journal of Biological Physics* **18 (4):** 261-269, full text**:** http://www.ngds-ku.org/Papers/J13.pdf
52. Kamal, S. A. & M. A. K. Yosufzai (1979, October 17-19). Moiré contour recorder. *The Nineteenth Annual Science Conference*, the Quaid-é-Azam University, Islamabad, Pakistan, p. 5, full text**:** http://www.ngds-ku.org/Papers/C04.pdf
53. Kamal, S. A., M. Sarwar & M. K. Rajput (2012, December 27-29). Crystal-structure concepts applied to static and dynamic modeling of the human spinal column. *The International Conference on Condensed-Matter Physics and Engineering*, the Bahauddin Zakaria University, Multan, Pakistan, p. 81, abstract**:** http://www.ngds-ku.org/Presentations/BZU1.pdf
54. Kamal, S. A., M. Sarwar & M. K. Rajput (2014*a*, September 4). Crystal-structure-

concept-based modeling of the human-spinal column validated through 3-D-bone scanning. *The Second Conference on Anthromathematics and Sport Mathematics in the Memory of (Late) Hussain Ahmed Bilgirami (ANTHROMATHEMATICS 2014)*, Department of Mathematics, University of Karachi, Karachi, Pakistan and Government College, Hyderabad, Pakistan, p. 8, abstract#Anthro14-04**:** http://www.ngds-ku.org/Presentations/Spinal.pdf

55. Kamal, S. A., M. Sarwar & U. A. Razzaq (2013*a*, September 4, 5). Anthromathematics of the human spinal column. *The First Conference on Anthromathematics in the Memory of (Late) Syed Firdous (ANTHROMATHEMATICS 2013)*, Department of Mathematics, University of Karachi, Karachi, Pakistan and Government College, Hyderabad, Pakistan, p. 7 (Prof. Dr. Z. K. Kazi and Prof. Dr. M. A. Shah memorial lecture), abstract#Anthro13-01**:** http://www.ngds-ku.org/Presentations/Scoliosis.pdf
56. Kamal, S. A., M. Sarwar & U. A. Razzaq (2015*a*). Effective decision making for the presence of scoliosis. *International Journal of Biology and Bio-technology* **12 (2):** 317-328, full text**:** http://www.ngds-ku.org/Papers/J36.pdf
57. Kamal, S. A., N. Jamil & S. A. Khan (2011*a*). Growth-and-Obesity profiles of children of Karachi using box-interpolation method. *International Journal of Biology and Biotechnology* **8 (1):** 87-96, full text**:** http://www.ngds-ku.org/Papers/J29.pdf
58. Kamal, S. A., N. Saeed, M. S. Saleem *et al.* (2011*b*, December 21, 22). Anthromathematics of MUAC. *The International Conference on Physics and the World of Today in the Memory of Prof. Dr. Sheikh Ansar Husain*, Department of Physics, University of Karachi, Karachi, Pakistan, p. 66 (invited lecture), abstract#45**:** http://www.ngds-ku.org/Presentations/Physics3-2.pdf
59. Kamal, S. A., S. A. Ansari & S. S. Jamil (2014*b*, September 4). Growth-and-Obesity Enhanced-Raodmaps of children. *The Second Conference on Athromathematics and Sport Mathematics in the Memory of (Late) Hussain Ahmed Bilgirami (ANTHROMATHEMATICS 2014)*, Department of Mathematics, University of Kara-chi, Karachi, Pakistan and Government College, Hyderabad, Pakistan, p. 10, abstract#Anthro14-06**:** http://www.ngds-ku.org/Presentations/Enhanced.pdf
60. Kamal, S. A., S. A. Ansari & S. S. Jamil (2015*b*). Generating and validating Growth-and-Obesity Roadmaps for the Pakistani children. *International Journal of Biology and Biotechnology* **12 (1):** 47-61, full text**:** http://www.ngds-ku.org/Papers/J35.pdf
61. Kamal, S. A. & S. A. Husain (1978, November 6-8). Cross lattice and eigenfunctions. *All Pakistan Mathematical Conference*, the NED University of Engineering and Technology, Karachi, Pakistan, p. 4, abstract**:** http://www.ngds-ku.org/pub/confabst2.htm#C03:
62. Kamal, S. A. & S. A. Husain (1988). A dimensionless-reciprocal lattice *Karachi University Journal of Science* **16 (1&2):** 23-27, full text**:** http://www.ngds-ku.org/Papers/J07.pdf
63. Kamal, S. A. & S. A. Khan (2015). Hairstyle, footwear and clothing for gymnastic activities in the primary-school setting. *Pamukkale Journal of Sport Sciences* **6 (3):** 29-45, full text**:** http://www.ngds-ku.org/Papers/J37.pdf

64. Kamal, S. A., S. F. A. Rashid, U. Rehman, *et al.* (2011*c*, December 21, 22). Verification of conversion formulae for MUAC on skin and clothing. *The International Conference on Physics and the World of Today in the Memory of (Late) Prof. Dr. Sheikh Ansar Husain*, Department of Physics, University of Karachi, Karachi, Pakistan, p. 62 (poster presentation), abstract#42**:** http://www.ngds-ku.org/Presentations/Physics3-3.pdf
65. Kamal, S. A., S. J. Alam & S. Firdous (2002, June 22). The NGDS Pilot Project**:** A software to analyze growth of a child (a telemedicine perspective). *The National Telemedicine Conference Pakistan 2002*, Technology Resource Mobilization Unit (TreMU), Ministry of Science and Technology, Government of Pakistan, Islamabad, Pakistan, p. 2, full text**:** http://www.ngds-ku.org/Papers/C52.pdf
66. Kamal, S. A., S. K. Raza & M. Sarwar (2016*d*). Mathematical modeling of scoliosis indicators. *International Journal of Biology and Biotechnology* **13 (3):** 471-484, full text**:** http://www.ngds-ku.org/Papers/J42.pdf
67. Kamal, S. A. & S. S. Jamil (2012). A method to generate Growth-and-Obesity Profiles of still-growing parents. *International Journal of Biology and Biotechnology* **9 (3):** 233-255, full text**:** http://www.ngds-ku.org/Papers/J30.pdf
68. Kamal, S. A. & S. S. Jamil (2013, September 4, 5). From anthropometry to anthrodynamics**:** A bridge through anthromathematics. *The First Conference on Anthromathematics in the Memory of (Late) Syed Firdous (ANTHROMATHEMATICS 2013)*, Department of Mathematics, University of Karachi, Karachi, Pakistan and Government College, Hyderabad, Pakistan, p. 15 (opening lecture), abstract# Anthro13-09**:** http://www.ngds-ku.org/Presentations/Anthrodynamics.pdf
69. Kamal, S. A. & S. S. Jamil (2014). KJ-regression model to compute optimal masses of extreme cases. *International Journal of Biology and Biotechnology* **11 (4):** 623-648, full text**:** http://www.ngds-ku.org/Papers/J34.pdf
70. Kamal, S. A., S. S. Jamil & U. A. Razzaq (2014*c*). Stunting induced by wasting — wasting induced by stunting**:** A case study. *International Journal of Biology and Biotechnology* **11 (1):** 147-153, full text**:** http://www.ngds-ku.org/Papers/J32.pdf
71. Kamal, S. A., S. S. Jamil & U. A. Razzaq (2014*d*, September 4). The evolution of anthromathematics (2010-2014). *The Second Conference on Anthromathematics and Sport Mathematics in the Memory of (Late) Hussain Ahmed Bilgirami (ANTHROMATHEMATICS 2014)*, Department of Mathematics, University of Karachi, Karachi, Pakistan and Government College, Hyderabad, Pakistan, p. 15 (the Hussain Ahmed Bilgirmai memorial lecture), abstract#Anthro14-01**:** http://www.ngds-ku.org/Presentations/Anthromathematics2010-4.pdf
73. Kamal, S. A., S. S. Jamil & S. A. Ansari (2013*b*, September 4, 5). Growth-and-Obesity Roadmaps of children. *The First Conference on Anthromathematics in the Memory of (Late) Syed Firdous (ANTHROMATHEMATICS 2013)*, Department of Mathematics, University of Karachi, Karachi, Pakistan and Government College, Hyderabad, Pakistan, p. 8, abstract#Anthro13-02**:** http://www.ngds-ku.org/Presentations/Roadmap.pdf
74. Kamal, S. A., U. A. Razzaq & S. S. Jamil (2013*c*, September 4, 5). Importance of standardization of anthropometric protocols. *The First Conference on Anthromathematics in the Memory of (Late) Syed Firdous (ANTHROMATHEMATICS*

2013), Department of Mathematics, University of Karachi, Karachi, Pakistan and Government College, Hyderabad, Pakistan, p. 12, abstract#Anthro13-06**:** http://www.ngds-ku.org/Presentations/Anthropometry.pdf

75. Khan, A. R. & M. Naeemuddin (1999). *Kanz-ul-Imān*, Qudratullah and Co., Lahore, Pakistan, p. 51
76. Schutz, R. W. (1980). Sport and mathematics**:** A definition and delineation. *Research Quarterly for Exercise and Sport* **51 (1):** 37-49 (measurement and research design)
77. Siddiqui, K. A., S. A. Kamal, S. A. Husain & N. U. Khan (1993). Group structure of a covariant model of global-electrocortical activity. *Karachi University Journal of Science* **21 (1&2):** 35-38, full text**:** http://www.ngds-ku.org/Papers/J14.pdf
78. Sriraman, B. & L. English (2010). *Theories of Mathematics Education***:** *Seeking New Frontiers*, Advances in Mathematics Education, Spinger-Verlag, Berlin and Heidelberg (editors) — F. K. Lester, Jr.**:** On the Theoretical, Conceptual and Philosophical Foundations for Research in Mathematics Education, pp. 67-86; R. Lesh and B. Sriraman**:** Reconceptualizing Mathematics Education as a Design Science, pp. 123-146
79. Wasim, M., S. A. Kamal & A. Shaikh (2013). A security system employing edge-based rasterstereography. *International Journal of Biology and Biotechnology* **10 (4):** 613-630, full text**:** http://www.ngds-ku.org/Papers/J31.pdf
80. Williams, C. A., D. V. B. James & C. Wilson (2008). *Mathematics and Science for Exercise and Sport***:** *The Basics*, Routledge, London and New York
81. Wilson, M. (2009). An Absent City: Enigmatic Spatial Representations of Buenos Aires in Literature, Film and Comics *PhD Dissertation*, Cornell Theses and Collections, Cornell Digital Depository, Cornell University, Ithaca, New York, United States (unpublished), full text**:** http://hdl.handle.net/1813/13599

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