Unreasonable Success of Mathematics and the Role of IT in Driving National Economies
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I beg the indulgence of the Maha Sangha. Mr. Principal, esteemed teachers!

Distinguished guests! Friends and dear students!

I am honored by this invitation to deliver the Henry Steel Olcott Memorial Lecture of 2016. Colonel Olcott's Buddhist schools paved the way for upward mobility for millions of Sri Lankan children. I am one of them–I received my entire education from Grade 1 to Grade 12 at Ananda.

Why has Ananda College been so successful in nurturing future educators, mathematicians, physicians, engineers, military leaders, …those who have lead, innovated, and created? Why was it so effective in inculcating a value system of love for the motherland an appreciation of our Buddhist heritage and culture? Ladies and gentlemen! For that we are indebted to our teachers.   Newton said (in 1676) "If I have seen further, it is by standing on the shoulders of giants". Let us paraphrase "Giants lifted us up to put on a rung for us to climb". Ananda mathematics was synonymous with the late Mr. Charles Mendis Weeraratne. He was a great mentor who sowed in us the seeds of love for mathematics. On this occasion, I would like to pay a special tribute him. He was an Old Anandian himself. For forty years he taught advanced mathematics, geometry, trigonometry, calculus, and applied mathematics. He introduced us to calculus in Grade 9. How many schools in the United States boast that feat? He could not be more happier to see so many of his pupils here.

The nature of the relationship between mathematics and the physical world has been a source of debate since the era of the Pythagoreans. A school of thought, reflecting the ideas of Plato, is that mathematics has its own existence. Flowing from this position is the notion that mathematical forms underpin the physical universe and are out there waiting to be discovered. The opposing viewpoint is that mathematical forms are objects of our human imagination and we make them up as we go along, tailoring them to describe reality. In 1921, this view led Einstein to wonder, "How can it be that mathematics, being after all a product of human thought which is independent of experience, is so admirably appropriate to the objects of reality?" In 1959, Eugene Wigner coined the phrase "the unreasonable effectiveness of mathematics" to describe this "miracle," conceding that it was something he could not fathom.

The success of mathematics lies in its abstract formulations. The same laws govern apparently many different phenomenon. If we say 2+2=4, it is an abstract statement. If we say if I have 2 cows in one field and 2 in another then I have total of 4 cows, that is not an abstract statement but it is context-driven and tangible. European call option is an option to buy (100 shares) of an underlying security such as a stock at a prescribed price (the strike price) at the end of a prescribed time period. This helps to protect investors from the random price fluctuations of the security. The holder of an European call option maturing in six months with a strike price of $100.00 would only exercise his right to buy only if the price would be over a $100.00. If the price is $102.00 s/he would receive $2.00. If the price was, say $98.00, the holder would not exercise the option to buy. Thus the call option has benefits to the holder, hence it has an intrinsic value. How to price an call option? The fundamental problem is the random nature of the price of the security. Black and Scholes discovered a formula (published in 1973) for pricing call options. They created an instantaneously risk-free portfolio that included the Option, other securities, and bonds. Then portfolio was valued by using US treasury bonds. They had to solve a partial differential equation (PDE) subject to certain boundary conditions which lead to the price of the call option. After a transformation, the PDE became the heat equation, which was then solved. The point is what has heat got to do with the stock market? This is aa example of a technique discovered to solve one problem was also used solve another albite in a a very different context. We see the power of abstraction.

Why is exposure to mathematics so important part of the general education? It fosters critical thinking, problem solving skills, transfer of knowledge, reflection, inquiry, etc. Plato in the Republic asks Socrates "have you noticed how those who are naturally good at calculation are nearly always quick at learning anything else"? About 10 years ago, I was an experimenter in the Keystone project of Yoram Sagher and Vali Siadat. We worked with a community college of where students had to undergo remediation in college algebra. Both the control group and the experimented group of students were given pre and post tests on standardized nationally recognized English comprehension tests. The experimented group of students were tasked (twice a week for 30-40 min) with completing standard algebraic operations under a time sensitive environment. Of course no "English" was taught. We consistently demonstrated over a sustained period of five years, the students who did the repeated calculations within a given time period scored significantly higher in the post English comprehension tests. Repetitive calculations had improve their concentration skills. The Chronicle of Higher Education data shows the percentage by which the mean score of test takers from specific undergraduate majors differs from the mean score of all test takers. For mathematics majors the numbers are 12.8% in LSAT and 13.3% in GMAT.

In 1966, 4.5% of American college majors were in mathematics.

In the early 1970's, the attractiveness of the mathematics major started a dramatic decline. The percentage of freshman interested in a mathematics major dropped from 4.5% in 1966 to 3.2% in 1970 to 1.1% in 1975 (and never rose above 1.5% again) (data here come from the National Science Foundation). From 27,000 math degrees awarded in 1970, the number declined to 18,000 a year in 1975 (it was projected to be 50,000 a year in 1975) and 11,000 a year in 1980. The 1975 CBMS enrollment survey revealed a shift of student interest away from pure mathematics courses, a number of which saw 70% enrollment declines from 1970 to 1975, while applied mathematics courses registered modest declines. Internally, the more theoretical curriculum may have overwhelmed some students at the same time that the new computer science major offered an attractive, career-oriented alternative. The decline in interest in the mathematics major stabilized and slowly the number of majors rebounded a little in the 1980's.

There were three themes in the mathematics curricular. One was one that emphasized the connection to physics suited for preparation for industrial careers; a second emphasized pure mathematics of abstract algebra, real analysis., etc which was suited for preparation for graduate school and college teaching; a third theme in the formative stages involving mathematics of "organized complexity" to use a term coined by Warren Weever. While calculus and physical laws give you a simple global description of most physical phenomena but subjects such as statistics, operations research, and computer science involve complex structure of information that cannot be simply described. In this curriculum saw the introduction of discrete mathematics course covering set theory and applications to probability and statistics.

The second theme emphasizing pure mathematics as a major became dominant in 1960s. The emphasis on graduate School preparation in the mathematics majors seem to have be inappropriate for the average student, but most students were happy with the program; they came prepared to navigate the program and jobs were available after graduation.

In 1970 student attitudes changed and they became anti-science and anti-business. Science program enrollments drastically declined, but the mathematics major held. However, in the late 1970s saw significant decline in enrollment contrary to the expectations of the mathematics departments. Under preparation and less disciplined study habits caused high attrition; industry started demanding problem solvers not theoreticians. Fiscal constraints restricted the hiring of new teachers and teaching jobs were drying up. Moreover, many students with high mathematical skills started migrating to computer science. However, mathematics departments neglected teaching statistics and computer science. In 1975 the majority of statistics courses were taught in biological and social studies departments and separate computer science departments were being set up.

The current guidelines by the Mathematical Association of America, MAA, to modernize the mathematical curricular for baccalaureate degrees recognize the befits of learning mathematics. Lets take a quick look at the recommendations (taken ad verbatim from the MAA).

Cognitive Recommendation 1: Students should develop effective thinking and communication skills.

Major programs should include activities designed to promote students' progress in learning to

- state problems carefully, articulate assumptions, understand the importance of precise definition and reason logically to conclusions;
- identify and model essential features of a complex situation, modify models as necessary for tractability, and draw useful conclusions;
- deduce particular instances from general principles;
- use and compare analytical, visual, and numerical perspectives in exploring mathematics;
- assess the correctness of solutions, create and explore examples, carry out mathematical experiments, and devise and test conjectures;
- recognize and make mathematically rigorous arguments;
- read mathematics with understanding;
- communicate mathematical ideas clearly and coherently both verbally and in writing to audiences of varying mathematical sophistication;
- approach mathematical problems with curiosity and creativity and persist in the face of difficulties;
- work creatively and self-sufficiently with mathematics.

Cognitive Recommendation 2: Students should learn to link applications and theory.

1. Mathematics students should encounter a range of contemporary applications that motivate and illustrate the ideas they are studying, become aware of connections to other areas (both in and out of the mathematical sciences), and learn to apply mathematical ideas to problems in those areas.
2. Students should come to see mathematical theory as useful and enlightening in both pure and applied contexts.

Cognitive Recommendation 3: Students should learn to use technological tools.

Mathematical sciences major programs should teach students to use technology effectively, both as a tool for solving problems and as an aid to exploring mathematical ideas. Use of technology should occur with increasing sophistication throughout a major curriculum.

Cognitive Recommendation 4: Students should develop mathematical independence and experience open-ended inquiry.

A mathematical sciences major should be structured to move students beyond the carefully choreographed mathematical experiences of the classroom. A major curriculum should gradually prepare students to pursue open-ended questions and to speak and write about mathematics with increasing depth and sophistication.

Content Goals

Content Recommendation 1: Concepts and methods from calculus and linear algebra.

Content Recommendation 2: Students majoring in the mathematical sciences should learn to read, understand, analyze, and produce proofs at increasing depth as they progress through a major.

Content Recommendation 3: Mathematical sciences major programs should include concepts and methods from data analysis, computing, and mathematical modeling.

Working mathematicians often face quantitative problems to which analytic methods do not apply. Solutions often require data analytics, complex mathematical models, simulation, and tools from computational science. To meet these workplace expectations every mathematical sciences major should have, at a minimum:

- command of data analysis and statistical inference at a level equivalent to that attained in an applied data analysis course;
- experience working with professional-level technological tools such as computer algebra systems, visualization software, and statistical packages;
- modest experience writing computer programs;
- experience tackling ill-posed real-world problems by building and analyzing appropriate deterministic and stochastic mathematical models.

Content Recommendation 4: Mathematical sciences major programs should present key ideas and concepts from a variety of perspectives to demonstrate the breadth of mathematics.
Programs should present key ideas from a variety of perspectives, employ a broad range of examples and applications to motivate and illustrate the material, promote awareness of connections to subjects both within and beyond the mathematical sciences, and strengthen each student's ability to apply the course material to these subjects. Programs should introduce historical and contemporary topics and applications, highlighting the vitality and importance of modern mathematics, and the contributions of diverse cultures.

Content Recommendation 6: Mathematical sciences major programs should present key ideas from complementary points of view: continuous and discrete; algebraic and geometric; deterministic and stochastic; exact and approximate.

Students acquire mathematical depth and perspective by encountering and employing a variety of mathematical viewpoints:

- Continuous and discrete: Continuous mathematics—calculus, analysis, and differential equations—has long been central to mathematics major curricula. In recent decades, however, advances in computer science, operations research, mathematical modeling, and data analysis have dramatically increased the importance of discrete mathematics. Techniques from discrete mathematics —difference equations, recursive methods, combinatorial arguments, graph-theoretic models —prepare students to encounter the rich interplay between continuous and discrete approaches in future study and careers. Discrete mathematics should therefore take its place alongside continuous mathematics as a crucial element of undergraduate study.

- Algebraic and geometric: Algebra and algebraic structures—vector spaces, groups, rings, fields—are fundamental to mathematics and should be included in every undergraduate mathematics curriculum. Geometry and visualization are different ways of thinking and provide an equally important perspective. A geometry course is a useful part of any student's major program and is essential for future high school teachers. But geometric viewpoints should appear beyond geometry courses. Geometric reasoning and visualization complement algebraic thinking in linear algebra and multivariable calculus, and remain important in more advanced courses such as real analysis and differential equations.

- Deterministic and stochastic: New applications of mathematics to the biological and social sciences make understanding and modeling randomness and random phenomena increasingly important in undergraduate mathematics. Students should see the need for and master basic methods associated with elementary discrete and continuous-time stochastic models. Deterministic models can fruitfully represent large-scale behavior, but random variation is often better seen through the stochastic lens. Stochastic applications appear naturally in statistics courses, but can also be introduced in courses such as elementary probability, matrix algebra, or graph theory. They can be explored further in courses such as differential equations or mathematical models

- Exact and approximate: Students should be able to use, and evaluate approximations, understanding that exact answers, although desirable, are often unavailable or impractical. Students should be introduced to numerical methods, discrete approximations of continuous phenomena (and vice versa), and the general role of approximation in solving problems.

Balancing a variety of mathematical perspectives need not mean devoting separate courses to each. A more feasible strategy is to structure the curriculum and requirements intentionally to include these themes over the course of a student's major. For instance, modern computing tools—which themselves combine graphical, numerical, and algebraic resources—can facilitate presenting these viewpoints in many undergraduate courses.

Content Recommendation 7

At least one mathematical area in depth, Probability and Mathematical Statistics, Real Analysis I/II, and Abstract Algebra I/II.

Content Recommendation 8: Students majoring in the mathematical sciences should work, independently or in a small group, on a substantial mathematical project that involves techniques and concepts beyond the typical content of a single course.

Every major student should have a high impact" experience that requires substantial work in mathematics outside the carefully scripted environment of ordinary course work. Students should present their results in written and oral forms. Institutions can provide this opportunity in various ways: undergraduate research experiences, courses driven by inquiry or open-ended problem solving, capstone courses, internships or jobs with a substantial mathematical component, etc.

Let us now spend a little bit of time how to teach the content.

1. The meaning of `knowing' has shifted from being able to remember and repeat information to being able to find and use it." (National research Council, 2007).
2. Tell me and I forget, show me and I remember, involve me and I understand.

Among the many student centered pedagogies, we have adopted (variants of) Inquiry Based Learning, IBL.

1. It is a student-centered approach that engages students in investigating real world questions.
2. Students are more involved in the construction of knowledge.
3. Students acquire and analyze information, provide solutions, and demonstrate their thinking and make their learning visible.
4. Inquiry based learning place students at the center of the learning process and teachers in the role of learning facilitator.
5. Inquiry-based Learning asks questions that come from the higher levels of Bloom's Taxonomy.
6. Inquiry-Based Learning involves questions that are interesting and motivating to students.
7. Inquiry-based Learning utilizes a wide variety of resources so students can gather information and form opinions

The Benefits of Inquiry based learning

1. Teaches problem-solving, critical thinking skills, and disciplinary content.
2. Promotes the transfer of concepts to new problem questions.
3. Teaches students how to learn and builds self-directed learning skills.

4. Develops student ownership of their inquiry and enhances student interest in the subject matter.

Cyril Ponnamperuma, at the inauguration of the IFS recalled, Cecil Powers advocating for starting basic research in post-war Europe …In the long run, it is most painful and very expensive, to have only a derivative culture and not one's own, with all that is implied in independence, in thought, self-confidence, and technical mastery…"

Powell's words alluding to the early 1950's where the United States was far ahead of Europe but it is very relevant to us. Let us all work together to build a school of Sri Lankan mathematicians. It will give an unrivaled identity, common purpose in national building at a relatively low investment.

Thank you for listening to me. May the blessings of the Triple Gem be with you.

11 Responses to "Unreasonable Success of Mathematics and the Role of IT in Driving National Economies"

1. *S.Gonsal* Says:
   November 24th, 2016 at 3:15 pm

   Both the control group and the experimented group of students were given pre and post tests on standardized nationally recognized English comprehension tests. The experimented group of students were tasked (twice a week for 30-40 min) with completing standard algebraic operations under a time sensitive environment. Of course no "English" was taught. We consistently demonstrated over a sustained period of five years, the students who did the repeated calculations within a given time period scored significantly higher in the post English comprehension tests.

   I wonder whether vice versa is also true.
   That is those who can't comprehend a simple writing fast and jump to wrong conclusions CANNOT BE good in Mathematics.

2. *Ananda-USA* Says:
   November 24th, 2016 at 3:31 pm

   And you the Kalawedda (Gon-Gonsal) is the man to pontificate on comprehension by others?

   Don't make me laugh out loud!

   What a jackass!

3. *Lorenzo* Says:
   November 24th, 2016 at 3:32 pm

   I AGREE.

   SL people's math skills are POOR. They should develop.

   MOST SL politicians are horribly poor in maths.

4. *S.Gonsal* Says:
   November 24th, 2016 at 3:53 pm

   Ha Ha Ha ! Mervyn Ayya Toppiya Daagena

5. *S.Gonsal* Says:
November 25th, 2016 at 5:36 pm

"SL people's math skills are POOR. "
No. I don't agree with this. Our maths skills are higher than average. Our people, as a nation, make the correct decision. They are able to asses all data and come out with the correct solution of their own.

Only problem is, similar to any other nation, those eagles and crocodiles DESTORY THE CHOICES people have and they are compelled to choose the lesser evil available at that time.

Individuals continuously need to make effort to develop intelligence throughout their lives. Once you think YOU ARE THE SMARTEST IN THE WORLD, from that day onwards YOU BECOME THE GREATEST FOOL. Fools can only fool themselves.

6. *Ananda-USA* Says:
November 25th, 2016 at 8:53 pm

I tell you in a positive way,
Don't tie me donkey down there!
Jackass a jump and bray,
Jump and bray,
Jump and bray!

—Harry Belafonte

7. *S.Gonsal* Says:
November 25th, 2016 at 10:02 pm

The fool who knows that he is a fool can, for that reason, be a wise man; but the fool who thinks that he is wise is, indeed, called a fool.
– Gauthama Buddha

8. *Ananda-USA* Says:
November 26th, 2016 at 12:10 am

Kalawedda (Gonsal),

Religion is the LAST refuge of the devious CROOK they say! When you can't defend yourself by temporal reasoning, you wrap yourself up in religion, desecrating the memory of those who should be revered!

SHAMELESS!

9. *S.Gonsal* Says:
November 26th, 2016 at 12:38 am

Above was a quote Budhdha – quoting it is not a going to refuge of a religion.
You can quote from a Harry Bealafonte , I cannot quote from Buddha.
What kind of Buddhist are you ?

Yes.

I go to refuge of Budddha , I have no other refuge
I go to the refuge of Dhamma, I have no other refuge
I go to the refuge of Sangha, I have no other refuge

I don't go to refuge of USA.

Who is the crook ?
Let people decide.

10. *Ananda-USA* Says:
November 26th, 2016 at 12:52 am

Kalawedda (Gonsal),

I am a Buddhist who does not drag in Lord Buddha to settle my petty arguments with others.

I use temporal solutions for temporal problems, without desecrating the name of those who should be revered.

Only CROOKS hide in religion when they can't defend themselves any other way.

SHAMELESS!

11. *S.Gonsal* Says:
November 26th, 2016 at 4:20 am

I am a FULL TIME Buddhist unlike you my firend.
I go to refuge of Buddha, Dhamma and Sangha whole my life 24/7

I don't need any other westerner's name to go and hide as I have nothing to hide.
I use Buddha's words to define what is right and wrong
I don't need a USA appended to my name to give me strength
I have the strength of TRUTH the tripple Gem.

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