PROPOSED VISSION FOR TEACHING & LEARNING STEM SYNERGIC INTEGRATION OF [INQUIRY, STEM and SYSTEMIC] APPROACHES

A.F.M. Fahmy*& Iftikhar Imam Naqvi**,
*Department of Chemistry, Faculty of Science, Ain Shams University, Cairo, Egypt
**Department of Chemistry, University of Karachi, Karachi, Pakistan
Corresponding Email: afmfahmy42@gmail.com

ABSTRACT

Presently we live in the period, categorized as the era of the fourth industrial revolution (4IR). This era makes way for the promises which are characterized by the fusion of the digital, biological, and physical worlds. Ample opportunities have ushered owing to the growing utilization of new technologies such as artificial intelligence, cloud computing, robotics, 3D printing, and the Internet availability in our daily lives. In addition to that advanced wireless technologies, among others, have culminated into economic disruption with uncertain socio-economic consequences. This situation demands that we bring about such amendments in our educational systems that it caters for the 4th IR era. It is thus necessary for scientists and educators around the world to strongly support the education system that promotes learning of science with other fields under the umbrella of STEM. Because it prepares professionals who can transform society to innovation and sustainable solutions in the 4th IR era. Due to technology innovation and growth in the knowledge-related economy, there is a need for inculcating targeted and strategic skills, and that STEM is responding to the changing technological world. However, in order to circumvent its few shortcomings this method needs some improvisation which are being put forward in this presentation of ours and it suggests to employ a synergy of inquiry approach, STEM and SA teaching methodologies, which we believe that it enhances the student systems (systemic) thinking ability that enable them to build alternative benign creative systemic solutions for the global energy crisis, and then choose between them. *[African Journal of Chemical Education—AJCE 12(1), January 2022]*

INTRODUCTION

On working and living in the 21st century and with the development of communication media and the ease of information flow, the world seemed to be living in a small village full of technological developments and a huge flood of knowledge. As the humans are coping with the era of fourth industrial revolution (4IR) [1] they are faced by challenges which are characterized by the fusion of the digital, biological, and physical worlds, along with the growing utilization of new technologies such as artificial intelligence, cloud computing, robotics, 3D printing etc.

In addition to that the Internet connectivity and advanced wireless technologies, among others have ushered in a new era of economic disruption with uncertain socio-economic consequences. Today's graduates will be facing tasks that are likely to emerge as a part of what the (4IR) is associated to. For most of the people around the world, the prospect of a future in which robots and computers are expected to take over many human jobs is a source of profound personal concern. So, the new generation has challenges that are difficult and numerous. For a prospective job seeker, it is going to be cumbersome to find his place in this technology prone world. Thus they fear that international flood of science, technology, and engineering will take away present prospects of their economic wellbeing.

Thus in order to ensure better future for young ones an alternative teaching methodology is the order of the day. Engineers, scientists, and educators have desired thus to develop educational systems to ensure that the coming generation is equipped with the best skills that cater for the

demands of the present 4th IR era. Hence in the last five years or so many developed nations found it necessary to introduce a newer learning methodology STEM [2,3,4]. This teaching methodology has been said to carry a number of advantages as underscored below:

(i) it is directly related to human well-being as it develops skills that help to fulfil his needs to develop food, medicine, clothing, and renewable and clean energy resources,(ii) to face the challenges of the 4th industrial revolution that threaten jobs primarily due to automation, (iii) the increasing growth and competitiveness of economies and the consequent rise in the level of social development,(iv) to connect facts and concepts of science, technology, engineering, and math fields in a global context. Thus, STEM prepares professionals who can transform society to innovation and sustainable solutions in the 4th IR era.

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4th IR workforce and Expectations from STEM

The core importance of STEM education is to meet the needs of the future. It is presently believed that only STEM trained graduates will have skills to undertake more than 70% of the jobs in the future. These graduates will become part of the world economy and "the Fourth Industrial Revolution," an era defined by increased innovation, automation, machine learning and artificial intelligence, and widespread internet connectivity. Knowledge-rich industries, including professional, scientific, and technical services, show huge economic growth. Higher-skilled jobs

therein are more compatible with technology and innovation, which promote increase in productivity and acquisition [5]. Patent growth is one of the indicators of technology innovation and growth in the knowledge-based economy.

Accordingly, there is a dire need for inculcating targeted and strategic skills, and that STEM methodology is designed to respond to the changing technological world. STEM trained students are expected to be equipped with skills to shoulder designing and making required by the twenty-first-century jobs. It will minimize growing polarization of labor-market opportunities between high- and low-skill jobs. Thus unemployment, and underemployment, especially among young people is likely to drop. [1, 5]. Science, technology, engineering, and mathematics contents are associated with 75% of the fastest-growing occupations, innovations, and good salaries. A technology- and knowledge-driven economy needs workers trained in science, technology, engineering, and mathematics. The digital revolution and the accompanied increasing demands for designing and manufacturing are driving the growth of the creative sector which extends from arts to science and technology, creativity and innovation. STEM education should provide employees, both males, and females, with essential skills that promote innovation and productivity and support economic growth [5]. Each STEM branch brings a valuable contribution to a well-applicable education. Science gives learners a deep and global understanding of the world. It helps them to become better researchers and critical thinkers. Technology prepares students to work in an environment full of high-tech innovations. Engineering allows students to increase problem-solving skills and apply knowledge in new projects.

Mathematics enables students to analyse information eliminate errors, and helps to make prompt decisions in designing solutions. STEM education links these disciplines into a concrete system. It motivates and inspires young generations to create new technologies and innovative ideas.

STEM in everyday life [6]

STEM learning doesn't have to be limited to the classroom. Studying the STEM disciplines in schools can help kids to build confidence, enhance critical thinking and problem solving and develop soft skills that will be essential in their adult lives. Transferring these STEM skills into everyday problems will only help foster their current and future success. STEM can help with important life skills. You can integrate mathematical skills into everyday life in a useful way. STEM learning doesn't have to be limited to the classroom.

Objectives of STEM Approach

1. Converting pure scientific concepts into applications.
2. Contribute to modern methods of teaching sciences such as self-learning, discovery, inquiry, and systemic.
3. Developing the skills and abilities of the teacher and transforming him from a prompter into a guide for students that increases their creative abilities and leads them towards exploration.

4. To face the challenge of the 4th industrial revolution in the form of loss in jobs, primarily due to automation.
5. Integrating science, technology, engineering, and mathematics contents to provide students with the ability to address and investigate global problems and to devise plausible solutions.
6. Inculcate the students with an ability to seek continuous education and lifelong learning.
7. Effectively improve the students' learning outcomes, such as academic learning achievement, student motivation, attitude, problem-solving skills [6]

Teaching STEM Disciplines

At the beginning of the uses of STEM, "Science, Technology, Engineering, and Mathematics" fields were taught separately or in two fields like science and math [7]. But by adopting the STEM approach, the discipline plays a key role in shaping the classroom in an integrated manner, during which the fields are combined with each other to form an integrated educational system consisting of science, technology, engineering, and mathematics, which in turn provides creative and innovative ways to solve the problems for possible practical applications.

With the STEM learning strategy, the contents of the concepts from the four fields are not easier to address in the classroom. Lately, studies have surfaced that highlight many disadvantages of STEM. The biggest issue that disturbs STEM education at large is the lack of uniform guidelines and standards for what students should learn or what qualifications teachers require for teaching.

Every program at every STEM school is different. While they provide a foundational base, there's no uniformity regarding emphasis placed on specific subjects or skills. Against that when an inquiry-based STEM learning strategy was examined, the pilot study indicated that the inquiry-based STEM learning strategy could improve only gifted students' abilities in accordance with 21st-century learning frameworks [8].

Role of Teachers in STEM, Inquiry and Systemic Approaches

STEM teacher guides the students to examine problems from all angles by questioning. This pedagogy is student-centered and it involves the philosophy that students are capable of guiding their own learning. Teachers are just there to facilitate this student-led process [9]. The role of the teacher in the inquiry method is to be the primary mentor, advisor. Teachers can tell students where and how a resource is available for reference. This will help students find the right information if they are having trouble finding important information; students should do their research [10]. However, a Systemic teacher provides advice and guidance and helps students to clarify ideas, and connections between them This role can be a great way to pay individual attention to a student [11,12].It can also allow a teacher to tailor-make a course to fit specific student needs .

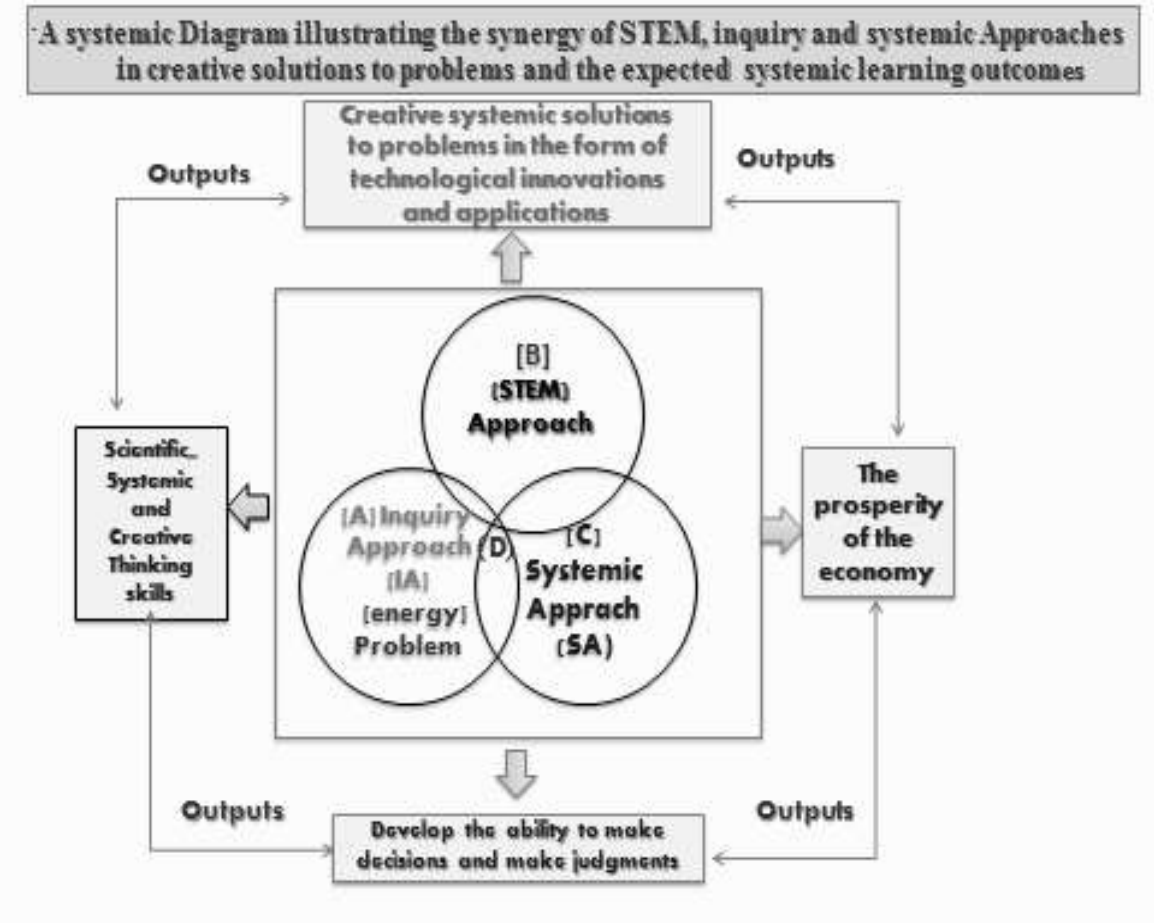
So the three approaches are student-cantered and the role of teacher is more or less advisor, and facilitator to guide students towards problem solving and inquiry learning that motivating them to solve the challenges.

THE PROPOSED TEACHING SCENARIO [SYSTEMIC DIAGRAM - (IDEA)]

Our proposed and redesigned scenario for teaching (STEM) fields is suggested to start with the *Inquiry approach (A) followed by the STEM Approach (B*), wherein (i) A student chooses a technology based problem (such as the energy problem) under the guidance of the teacher, (ii) Then the problem is highlighted and the relevant data and information is collected, (iii) the student starts suggesting ways to solve the problem. (iv) Student now makes use of STEM (B) to help resolving the problem , thereby using all or some of its fields (science, technology, engineering, and mathematics), (v) Subsequently comes to the role of the Systemic Approach (C), which is then integrated with the two other approaches to find the systemic solution by dealing with all aspects of the energy problem (due to its complexity) to develop a knowhow of the overlapping and intertwined systemic relationships between its aspects, (vi) the student can analyze the problem into its components and then build the systemic creative solutions through collecting information from all or some of the areas of STEM fields. So that creative solutions thus emerge (D) this in turn leads to some sort of innovations that provide solutions to address many other global problems.

Thus by integrating the three learning Approaches [INQIURY-STEM – SYSTEMIC], of course, one can approach a more efficient outcome against a possible result derived by any of the previous approaches. The creative Systemic solutions (D) will provide four systemic learning outputs instead (cf SD 1]. The other advantages are likely to be as follows:
i) the creative systemic solutions of the problems in the form of technological innovations applications,

ii) gain of scientific and systemic thinking by students, iii) Enhancement of the student's ability to make decisions and judgments, iv) the prospect of an economic turnaround.



Systemic Diagram [SD1] Illustrating the learning outputs of the synergy [Inquiry/ STEM/, Systemic] Approaches To teaching energy.

Common Denominators between the Three Approaches [Inquiry-STEM-Systemic] for Enhancing Learning outcomes

*Learning levels***:** It takes place at the higher levels of learning (analysis - synthesis - evaluation – creativity).

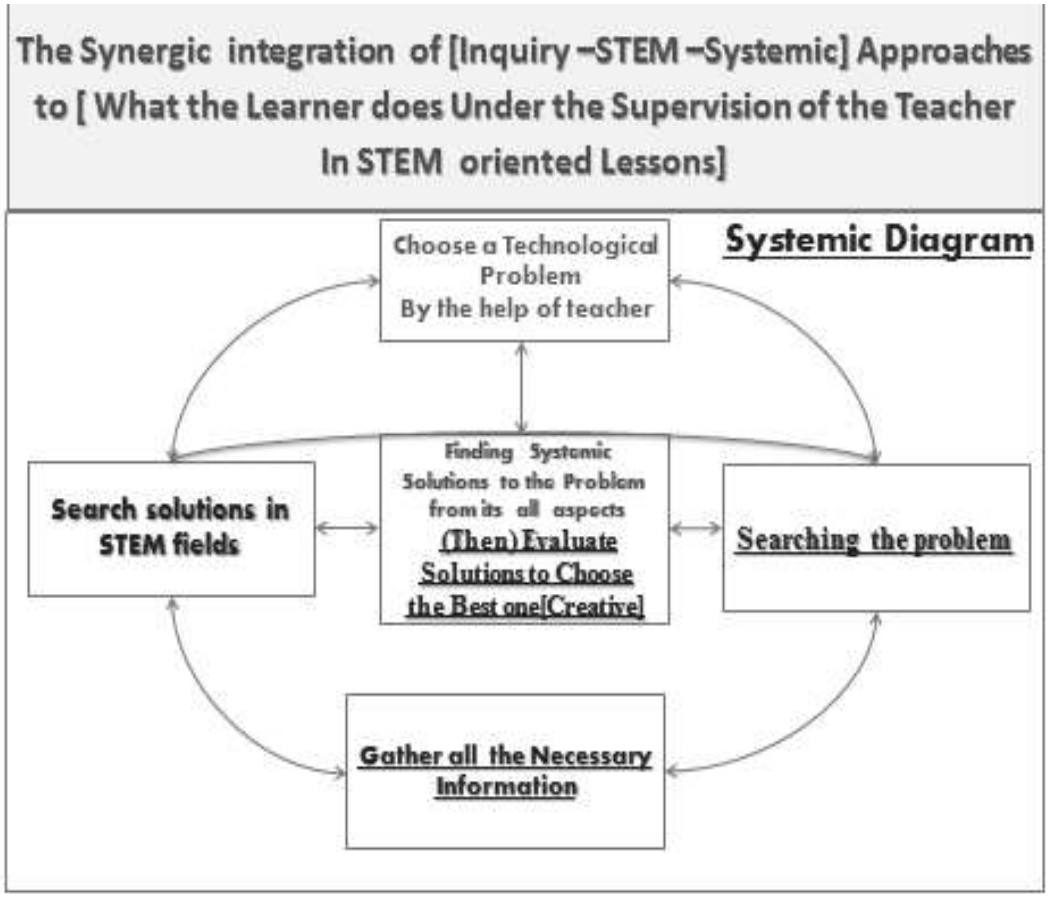
The role of the teacher: is a guide and motivator for students learning. *Learning environment*: Creates, active and stimulating environment for learning and innovation. *Teaching methods*: student gets oriented by teach himself how to resolve the scientific and technological problems by using Inquiry approach enhanced by the systemic approach, on all or some of STEM fields.

*Skills**:*** Students acquire many skills, including scientific, systemic, and creative thinking, the ability to make decisions and to make judgments .follow up references to gather information, process it, and be equipped with designing and innovation skills for the twenty-first-century jobs.

Why Synergic INQ-STEM-SA Strategies?

The principle of synergy says that common interaction of the system components lead to a result that is greater than the simple sum of components parameters. By using INQ- STEM- SA strategies, we evolve an interactive system of expected greater efficiency of teaching and learning [Synergy effect] by combining the benefits of three teaching strategies

together, than we would expect to get by using each one of these strategies.[cf SD2]



Systemic Diagram [SD2] illustrating what students contribute under teacher supervision
In the integrated [Inq. Stem, Systemic] Approaches

Proposed STEM Lesson about Energy

In the last decade, it has been recognized and practiced in a number of developed countries that educating their young generation in the disciplines that pertain to Science Technology Engineering and Mathematics will ensure a better future. Thus, the curricula have been developed to meet this end, known as STEM. However, a number of educationists are bringing forth their dissatisfaction about this methodology. They suggest that the teachers though inculcate a better understanding of the relevant issues; the students find it difficult to retain the knowledge imparted earlier. In this context, we propose that STEM approach if modified in such a way that it integrates human instinct of inquiry with STEM and then Systemic Approach it will provide a platform that will be highly suitable for the present day needs.

A scenario of teaching by integrated [INQUIRY.STEM. SYSTEMIC] Strategy. [cf. SD1]

1. Teacher introduces a topic by guiding students to an issue connected to real global problems. (Such as global energy crisis) and its positive and negative impacts on our daily life.
2. Then students decide to explore the issue of energy by identifying and collecting data and information [Inquiry based] [A] about global energy resources, types of energy, shortage of natural energy resources, and environmental problems due to misuse of energy resources.
3. Then the student starts searching energy resources by making use of STEM fields [B] [starting with science. Students will go through chemistry concepts like [bond energy,

physical and chemical changes, types of chemical reactions, thermochemistry-heat of reactions –heat of formation-heat of dissociation]. Then students go to the 1st Law of thermodynamics and exothermic reactions, including combustion of fossil fuels.

4. Then students use Math in calculating the amount of thermal energy obtained from exothermic reactions like the combustion of fuels. Then they apply mathematics to calculate the amount the thermal energy obtained from the combustion of a certain amount of fossil fuel.
5. Then go to Energy -transformations from thermal to mechanical energy in the internal combustion engine. Then students will learn the parts of the internal -combustion engine [by using Technology]. Then they get enabled to calculate engine efficiency which is the relationship between the total energy contained in the fuel, and the amount of energy used to perform useful work with the help of the teacher.
6. Then students under the guidance of the teacher will identify the global problems behind the combustion of fossil fuels like that of heavy traffic. The combustion of fossil oil gives CO2 and water besides Sulphur oxides (SOX) and nitrogen oxides (NOX) and these are believed to have a pollution effect on the environment, the atmosphere, and the ozone layer. [Air pollution, global warming, and finally environmental climate changes]. When perfect combustion occurs in the presence of pure oxygen and at ideal conditions, such as in a gasoline engine (Auto engine), 14 .7 kg of air is required for each kg of fuel (gasoline in this

example) and the combustion is ignited by a spark. The oxygen is consumed with the fuel because the combustion is complete [13].

7. Then students will discover what they can do for environmental protection. They will evaluate real-world applications of gasoline versus uses of new technologies like hybrid cars, battery power versus solar power.
8. Then the students go to a systemic approach to teaching and learning [SATL] to analyze the problem of global warming and the reasons behind it under teacher supervision.
9. Then the students come to the role of Engineering to design other alternatives of benign sustainable energy tools. Based on geothermal energy, wind energy, Bioenergy, and solar energy.
10. Then finally the student uses SATL& systemic thinking [Systems thinking] to build alternative benign systemic creative solutions for the global energy crisis, and then choose between them. [Choose the most creative, innovative solution; more economic. Minimum waste pollution and cleaner energy alternative] [C].

STEM Education Advantages [14]

1. Workforce Preparation. The most popular STEM argument is that it prepares students for the workforce. STEM teaches students critical thinking and innovation skills. These particular skills help tremendously in the workforce. Science and Math naturally lend themselves to

these particular skill sets too. Professionals often come in and work with students to provide real-world exposure to future career options.

2. Provides Future Career Potential. Because STEM education is meant to raise the 4th IR workforce, from programmers to engineers and scientists, and that these careers usually offer good salaries and benefits to workers.
3. Promotes Gender Equality. STEM is attempts to narrow the gap between male and female workers.

STEM Education Disadvantages [14]

1. Doesn't Start Early Enough. Too many STEM programs start too late for students.
2. Elitism. STEM programs cater better for students who are naturally motivated and prepared to succeed. Students who do not fit those criteria are often left behind.
3. Lack of Clear-Cut Standards. STEM approach suffers from a lack of a uniform curriculum. The biggest issue that disturbs STEM education at large is the lack of uniform guidelines for what students should learn or what qualifications teachers required for their jobs.

CONCLUSIONS

STEM education became a must in the era of 4th IR, because it prepares professionals who can transform society to innovation and sustainable solutions required to 4th IR . We believe that empowerments of STEM approach with two other successful approaches [Inquiry and systemic] will make it easier in the process of teaching and learning. The three approaches are student-cantered

and the role of teacher is more or less advisor, and facilitator to guide students towards systemic creative- Innovative problem solving of the global age.

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