



Enabling Students with 21st Century Competency Skills for Delivering Innovation

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ABSTRACT

In India, students' level of learning is measured through their reading, writing and arithmetic abilities. Although prerequisite, but these *are not sufficient* for excelling as individuals in the 21st century, for preparing future leaders within the nation and for expediting growth of a nation into an economic powerhouse. In our view, we need to equip students with a new extended skill set as identified by Partnership for 21st century skills (P21) so that they can apply their academic learning innovatively into new situations for overcoming day-to-day challenges in their lives and in the society. Therefore, a novel Conceptual Research Experience program was introduced at Indus World School in Indore(India), where selected secondary and higher secondary school students underwent research process and were encouraged to be creative, critically think, collaborate and communicate their research findings on a topic ranging from science and commerce to law and humanities. These students not only improved reading, writing and arithmetic abilities, but with better conceptual understanding were able to deliver an innovative solution for a practical problem and disseminate it at an international level, thus creating new opportunities for themselves and for their nation.

Indexing terms/Keywords

Research; Education; Teaching; School Students; Innovation; 21st Century skills

Academic Discipline And Sub-Disciplines

Education; Teaching

SUBJECT CLASSIFICATION

Teaching Methodology

TYPE (METHOD/APPROACH)

Project-based Learning; Scientific Inquiry

INTRODUCTION

India is home to one of the largest education system in the world. It has more than 230 million enrolments in over 1.4 million schools [7]. However, 3R's - Reading, wRiting and aRithmetic - are assumed to be the only essential skills for ensuring a successful future in terms of higher education, career and in-life [12]. Although these are important prerequisite but not sufficient in 21st century for excelling as individuals, preparing future leaders and expediting growth of a nation into an economic powerhouse.

Skills Gap In Indian Students

The Indian education ecosystem evaluates subject understanding and competence of students based on their abilities to read, write and compute numbers [7]. But, in the modern 21st century such an evaluation is not sufficient. Consider the example of Engineering, one of the most sought after degree in India which promises a potentially lucrative career. However, only 19% of engineering graduates in India are employable in the jobs for which they received training [1]. Why?

Former Chairman of Indian Space Research Organisation, G MadhavanNair, beautifully cap-tures the problem: Children are dealt with like almost in factory. At one end, they come-in and go through the speedo-trip with A or A+ (grades), which has no meaning in terms of knowledge [13]. Scoring marks in exams are important, but in todays world they cannot promise a prosper- ous career. Tony Wagner, Fellow at Harvard University puts this as: The world does not really care about what you know, rather all it cares is what you can do with what you know [16].

Wangers views are backed by Industry- the need for passionate people who can demonstrate with evidence that they can make difference in their workplace, beyond their scores and grades (Kohli 2016). But, the problem is that students are not able to demonstrate correlation between having a qualification and doing well at work within the current academic setting. Going back to our engineering example, majority of them cannot solve problems by cross application of concepts, nor can apply their concepts to practical problems [2]. Therefore, students enrolled in the educational institutes must be enabled to acquire workplace and life skills across multiple areas of knowledge for success. These value-added students, with their extra ordinary profile, will receive the best opportunities in life.

The culture of 21st century demands multiple areas of competency within an individual. It also demands ability to collaborate effectively with others, work independently with minimum/no supervision, solve problems using critical thinking, deliver innovative solutions to real practical problems and communicate clearly with all the stakeholders and peers. Therefore, apart from the 3R's, students must be trained on



these new set of 21st century skills within the K-12 setting. This will enable them to reflect on their surroundings, see patterns, ideate on new process, provide new solutions to problems and communicate effectively.

Need For Innovative Students

Innovations are directly linked to the innovativeness of people which is the prerequisite for growth, prosperity and economy of a nation and its citizens. The future of an economy, strength of democracy, and even the health of planets ecosystem depend on educating future generations to innovate [16]. However, in India, where 46.6% of population is below 24 years and literacy rate is 74.04% being Innovative Culture, Innovations and the link between them are missing [7]. Bloomberg, which is one of the most credible sources globally, ranks countries on their ability to innovate and identifies the top 50 [3]. It provides an overall score to each country based on six equally weighted metrics. These are:

- **Research & Development:** Research and development expenditure as a percentage of GDP
- **Manufacturing:** Manufacturing value-added per capita
- **High-tech companies:** Number of domestically domiciled high-tech public companies such as aerospace and defence, biotechnology, hardware, software, semiconductors, Internet software and services, and renewable energy companies - as a share of worlds total high-tech public companies
- **Postsecondary education:** Number of secondary graduates enrolled in postsecondary institutions as a percentage of cohort; percentage of labour force with tertiary degrees; annual science and engineering graduates as a percentage of the labour force and as a percentage of total tertiary graduates
- **Research Personnel:** Professionals, including PhD students, engaged in R&D per 1 million population
- **Patents:** Resident utility patent filings per 1 million population and per \$1 million of R&D spent; utility patents granted as a percentage of world total.

China, which is an emerging economy similar to India, is ranked in top 50 innovative nations by doing fairly well in all the six metrics *namely* R&D, Manufacturing, High-tech Companies, Education, Research Personnel and Patents. However, India is not able to secure place in the top 50 innovative nations [3].

Globally, India is ranked among the lowest countries in terms of their capacity for, and success in, Innovation. On the other hand, China is rapidly progressing towards being an economic power- house similar to the USA. This needs change for India, if India aims to become a global economic powerhouse. Considering the example of entrepreneurs who have succeeded despite less than ideal schools, we can all learn from the development of these innovators and how education ecosystem in India must change at school level to ensure that we create original innovators, for expediting Indian economy.

It is imperative that India creates an ecosystem of innovation and research. An environment where students are fed with creativity while providing skills for the future is essential. This will help India leapfrog into the future as a very progressive nation. Therefore, it is mandatory that our schools and universities become productive cogs in driving this wheel of innovation.

Need For Curiosity Among Students

According to Albert Einstein, curiosity has its own reason for existence and the most important thing is that students should not stop questioning. However, as pointed out by Nair, the outcome of factory production of students is indeed the opposite, that is non-curious students.

University of California (UC) recently conducted series of experiments to understand what exactly goes on in the brain when our curiosity is aroused. Their three most important research findings were that curiosity prepares brain for learning, curiosity makes subsequent learning more rewarding and curiosity makes learning more effective and enjoyable [8].

Students are better at learning information that they are curious about and this could be on any topic or area. For example, What Beatles single lasted longest on the charts, at 19 weeks?, What does the term dinosaur 'actually mean?' or 'Why India is not using Thorium to generate Electricity?' Therefore, instead of jumping straight into the answers to questions in the textbooks, it is important to start with the questions that prompt them to their own exploration for the answer.

Curiosity Prepares Brain For Learning

Although students are always better at learning information that they are curious about, but the research at UC also shows that curiosity helps students learn information that they don't consider interesting and important. However, asking right question such as How do machines help me build big things? or Why do I



need to wear a helmet when I ride my bike? are important for driving the curiosity among students. This is because curiosity puts the brain in a state that allows it to learn and retain any kind of information, similar to a vortex that sucks what you are motivated to learn and also everything around it.

Our educational ecosystem should *therefore* arouse students about something that they are naturally motivated to learn. This will in turn equip students to also learn things which were otherwise uninteresting or boring for them. Let's say that a student struggles to understand mathematics. So, using generic school textbooks as the only solution for learning mathematics is most likely to be unproductive. However, students learning experience could be enhanced by personalizing the mathematic problems to match the specific interest of the student and relate it with a practical application. This would ignite curiosity in the student with better engagement in mathematics subject and will allow student to even solve similar problem of mathematics in future.

Curiosity Makes Subsequent Learning More Rewarding

The scientists at UC also found that by igniting the spark of Curiosity among students can make their learning experience more rewarding. This is due to the increased activity in the hippocampus, the part of brain involved in the creation of memories. Therefore, curiosity can help students remember lessons and concepts taught in school which otherwise were problematic for many.

The activity is also increased in the brain circuit responsible for reward and pleasure, when students become curious. Dopamine, which is the *feel-good* chemical, relays the messages between neurons which give the kick to students to press hard for achieving success in answering the question. Sort of feeling when a human being gets something desirable such as money.

Curiosity makes Learning more Effective and Enjoyable

Questions stimulate curiosity among students [10,17]. As a result, they themselves make every effort to seek answers to improve their understanding. In turn, engaging with the academic literature with interest and understanding it's relevance within the practical context. Therefore, it is extremely important to instill strong desire among students to know or learn something by igniting curiosity.

Consider the example of Sir Isaac Newton, without curiosity would he have formulated the laws of physics or Alexander Fleming, could he have discovered penicillin or even Marie Curie, could she have asked question and conducted her pioneering research on radioactivity. If this is assumed history, consider more recent examples. Could Sergy Brin, Larry Page, Steve Jobs or Mark Zuckerberg see the problem around them, ask question, seek answer and build a unicorn business around their research findings. Surely, it would have not been possible.

THE SEVEN SURVIVING SKILLS OF 21ST CENTURY

Indian education ecosystem encourages the students to read, write and compute at school. However, most of them are not able to reflect on their readings, nor do they care about what they are reading *in terms of* understanding its relevance within the practical context. The implicit culture prevalent among the society is to get the task completed without understanding their meaning, and the task is to score maximum marks.

Consider History subject for example, students can memorize names and dates, but can majority explain the larger significance of the historical events? Instead, a culture of deep-learning needs to be promoted in the Indian education ecosystem, where students try to seek meaning from the taught materials and textbooks, make connections and develop a deeper understanding of the concepts [4].

In today's highly competitive knowledge driven global economy, deep-learning culture needs to be started from the schools for developing strong foundation among the students. The failure in doing so would put the nation in competitive disadvantage. This is because deep-learning ability is essential for preparing thinkers of tomorrow within India and for expediting its growth into an economic powerhouse by leveraging on their innovative thinking.

The curriculum, teaching methods and tests that students undergo in India were designed for the needs of another era. They are largely outdated and require re-design. The basic new skills of 21st Century for being successful in higher education, career and in-life are [16]: (1) Curiosity and Imagination, (2) Critical Thinking and Problem Solving, (3) Agility and Adaptability, (4) Accessing and Analysing Information, (5) Effective Oral and Written Communication, (6) Collaboration across Networks and leading by Influence and (7) Initiative and Entrepreneurialism.

Curiosity and Imagination

As discussed in the previous section Curiosity or the drive to know more is a very critical skill required in the 21st century students. It leads to greater imagination and introduces creativity in the students. Thus, creating pathway to delivering innovation. These are not only important to solve problems, but also in



developing new products, services, processes of social or commercial value. Students need to be new and improved knowledge workers those who can think in different ways, have a burning curiosity, lively imagination, can engage others empathetically and can progress society through their individual contributions.

Thinking and Problem Solving

Ability to ask good and thoughtful questions by critically thinking and strategically using the thoughts to solve problems is much needed in the 21st century students. As discussed earlier, employers and industry are looking for people who can apply their learning into new situations and across multiple disciplines.

Agility and Adaptability

Recent years has seen a great shift from the hierarchical authority (who tell what to do at the workplace) to more team-based environment (of collaborative working) where people not only need to think independently, but also devise agile strategies for the success of the team. They need to adapt for example, to different cultures, time-zones and cooperate with other team members in a very professional manner to meet the strict deadlines.

Accessing and Analysing Information

Internet has given people access to vast amount of information across regions and continents within in nanoseconds which needs to be processed and interpreted by the individuals. On the positive side, getting access to the information on World Wide Web is an important factor for driving curiosity and increasing the power of imagination, on the other hand it is also important to not assume that all information is true. One must be able to validate credibility of the information before consuming and accepting it.

Effective Oral and Written Communication

Communication skills are a major factor highlighted in dozen of studies over the years that focus on students lack of preparation for both college and workplace, and these skills are only going to become more important as teams are increasingly composed of individuals from diverse cultures.

Collaboration Across Networks and Leading By Influence

Progress in Digital Technologies implies that all project members need not be physically present at a place to execute the project. This is an era of virtual teams. Consider the example of Siemens, they have teams working on major infrastructure projects all over the USA. They work with people all around the world to solve a software problem. These people are not present in the same physical room, instead from their own locations they use variety of conference calling and web based technologies to conduct meetings and execute the project to success.

Initiative and Entrepreneurialism

World needs individuals who can take initiatives, demonstrate leadership in every aspect of their lives and posses entrepreneurial spirit to overcome challenges by seeking out new opportunities, ideas, and strategies for improvement. It requires innovators, thought-leaders and policymakers of tomorrow to create new economic opportunities and improve the society to greater levels through exemplary practises.

P21 FRAMEWORK FOR 21ST CENTURY LEARNING

Several governments, multinationals, industry experts, academics and educationalist around the world have worked together in various groups to identify and formalise 21st Century skills which students must possess in order to be successful in today's competitive world.

The Partnership for 21st Century Skills (P21), a leading public-private partnership in this effort, calssifies the important skills of the 21st century for the students as:

- **Learning and Innovation Skills:** Creativity and Innovation, Critical Thinking and Problem Solving, Communication and Collaboration (also referred as the'4Cs')
- **Information, Media and Technology Skills:** Information Literacy, Media Literacy and ICT Literacy.
- **Life and Career Skills:** Flexibility and Adaptability, Initiative and Self Direction, Social and Cross-Cultural, Productivity and Accountability.

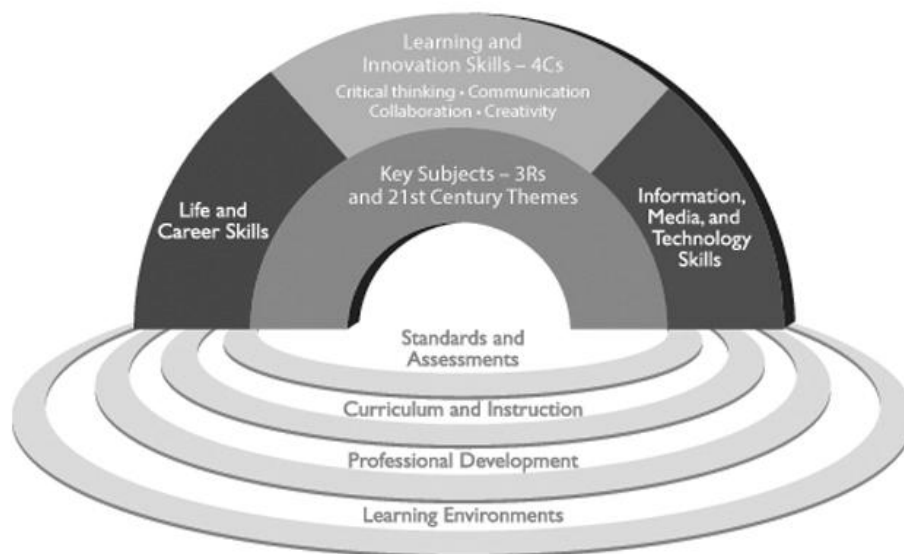


Figure 1: P21's Framework for 21st Century Learning

The framework (see Figure 1) encompassing these skills is built up on the old 3R's and the 'Seven skills to survive in the 21st Century' as proposed by Wagner. They recognise that in an interconnected, multicultural, technology driven world, awareness of multitude skills and working collaboratively in cross geographical, cross-cultural, multi talented teams in an inevitable reality of today. Therefore, it focuses on themes such as global awareness, financial, economic, business and entrepreneurial literacy, civic literacy, health literacy and environmental literacy.

Although, efforts like robotics, science fairs, design for change, model UNO do give the school students a platform to explore their talent, there continues to be a pressing need to provide students glimpses into their careers of interest through hands-on experience. It is of critical national importance that we enable our youth to acquire and interpret information through critical thinking and improve their cognitive abilities, which will embed Innovation culture in our society and allow research and development of (a large number of) original and innovative process and products in India. Their dissemination globally, as research based outputs (in the form of publications, patents and/or products), will build the brand 'Made in India' and allow India to rapidly become an economic powerhouse.

NEW CONCEPTUAL RESEARCH EXPERIENCE PROGRAM FOR STUDENTS

Conceptual Learning Experience (CRE) is a very innovative, unique and new skills development program which provides students the 21st century skills as stated in the P21's framework for 21st Century Learning along with delivering innovations by school students. This new CRE program is based on project and problem based learning techniques. Project and Problem based learning techniques have proven to be very effective at the University level as well as at the High School level [9]. Project and Problem based learning programs have long succeeded at arousing curiosity and igniting student learning [3,14,15,18].

The CRE program seeks to support the school students to develop deep-learning and innovation skills, in developing their capacity to design transformation and innovative solution for a problem, multi-modal learning experience across disciplines, their capacity to communicate effectively and all as a means to acquire the new skills in-demand today.

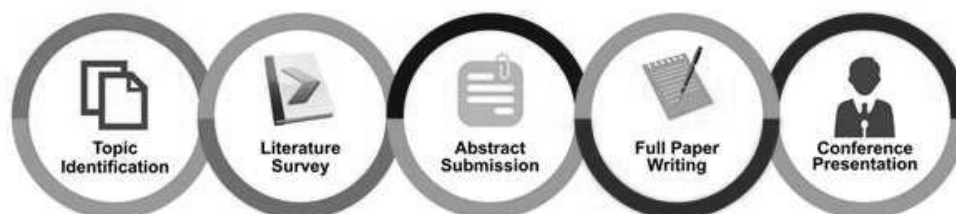


Figure 2: Process Flow (left to right) of Conceptual Research Experience Program for Students

The research-based training process which students undergo in order to acquire new skills and deliver an innovative answer to their question to global audiences is shown in Figure 2. The following section discusses the CRE training process in detail.



CRE Training Process

CRE program is aimed to enhance an attitude of questioning and wonder, where failure and confusion are not only accepted, but expected; and where technology was not perceived as a solution but rather as a context and tool for enquiry. In brief, the goal of CRE program is to deliver an original, innovative, research based answer to the question asked by the student [6].

CRE program is suitable for students from classes 7th to 12th and is delivered through web casts and monthly school visits. The training process is divided into the following 6 core stages:

- **Stage 1:** Identifying Students
- **Stage 2:** Topic Identification
- **Stage 3:** Literature Review
- **Stage 4:** Abstract Submission
- **Stage 5:** Full Paper Writing
- **Stage 6:** Conference Presentation

Stage 1: Identifying Students

A research expert conducts seminar(s) in the school for interacting with the students and informing students about the importance of having a differentiating value-added profile for gaining competitive advantage from others. The session is aimed to spark curiosity among the students, arouse students about something that they are naturally motivated to learn and drive interesting questions from them which they are willing to answer. For example, What Beatles single lasted longest on the charts, at 19weeks?, What does the term dinosaur actually mean? Or Why India is not using Thorium to generate Electricity?

The curiosity driven students from the session are asked to submit a short essay (2 page/1000words). The following questions are addressed in the essay by students:

- Their Question (in less than 10 words) as the title of the essay
- Previous Reading conducted Related to answering the question
- Summary of Potential Answers from their previous readings
- Practical Use of their answer

The questions students ask could be related to any field ranging from science and commerce to humanities and arts. They are asked to write an essay answering the above questions in order to ensure feasibility of the project, within the available resources and process time-frame. The essay by students also informs the research expert about the current state/attempts made by the student for answering the question.

A research expert, who is a PhD degree holder along with having Portfolio of publications in the area of the question asked by the student, invites students for a 1:1 web session. In this session, research expert explores student's question in detail along with the possible lines of enquiries. Students who demonstrate Curiosity, Creativity, Imagination and Oral Skills by further asking questions, and willingness to learn and share their answer with the global audiences are selected into the CRE program.

The selected students are segmented into a group of maximum 3 students by the subject expert, based on the similarity in their questions and integration of multi-disciplines. In case, questions of students do not overlap, they are asked to work individually.

Stage 2: Topic Identification

The questions asked by the students are further framed into a research topic in this phase. It is vital because the way person frames a complex issue or problem has significant influence on how they seek to understand it and solve. It is also equally important consuming and interpreting information from the surroundings and largely from the world. A well-framed topic of research will help the students to communicate their observations, results and understanding to the global audiences.

Students are guided to the most recent review papers based on their question for the initial investigation. The study of review papers provide them broad awareness and most up-to-date knowledge of the practises and problems prevalent in their area of interest. They are asked to de-construct their questions into micro problems for which the gap in knowledge (in literature) from their view is evident and could be shown as an concrete evidence in the final report or the research publication.

The students, in groups or individually, are also asked in this phase to write a project plan. This helps them to organize complex phenomenon in a coherent, understandable categories and separate relevant



aspects of a given phenomenon from the irrelevant aspects. The project plan, written by student, contains aims and objective of the research enquiry, gap in knowledge which their research will fill, practical use cases of the research and the time-frame using Gantt-Chart. The schedule of their activities, written by the student, provides them a strong sense of accountability to meet themselves and the project stakeholders.

All together, the project plan equips students with Agility and Adaptability skills as they frame the question into a feasible research topic. It develops their initiative and entrepreneurial skills as they seek out new opportunities, ideas and strategies for improvement. Project Plan also improves their ability to communicate through writing. The topic identification step emphasizes the value of clarity and order, seeking to organize activities and plans driven by theory which becomes lens for interpreting facts in the next stage of the process.

Stage 3: Literature Review

Literature Review stage assumes messiness, focuses on multiple theoretical perspectives, is tentative in application, comes with a belief in de-constructing the reading and questioning what one thinks as a fact through self-reflection and is driven more by bottom-up notions of the richness of practise. The aims of the Literature Review stage are:

- Minimize Contextual Gap
- Propose Innovative Solution
- Apply and Validate Solution

Stage 3a: Minimize Contextual Gap

Contextual Gap is defined as the difference in the context of the article written by author(s) and how the student understood the article after reading. It is used to test the conceptual understanding of the student using Active Reviews.

Active Review capture snapshot of an article in about 500 words and incubates deep-learning skill among the students. An article could be for example, scholarly research article, book, blog or even market-report depending on the student's research project. Students as a part of their Literature Review are guided to multiple articles and asked to prepare Active Reviews by answering the following questions:

- Aims and Objective of the article
- Problem
- Solution
- Results
- Practical Applications
- Relevance of the article to the Project of the Student

Active Reviews written by the student is examined by the mentor who is PhD expert in the subject area of the students project. Mentors award students a score out of TEN based on their understanding and also provides constructive feedback to the student. Since mentor is an external entity, it is assumed that the award of score and feedback will remain unbiased.

These small but regular assessments through Active Reviews provide, both students and the mentor, to convert the weaknesses of the student into strengths and improve student understanding across multiple disciplines. This step develops critical thinking skills in the student, and introduces abilities to access and analyse complex information in a simple manner. It also significantly influences students ability to creatively and innovatively think and pendown those thoughts in mind clearly in writing. The better understanding of concept allows students accept or reject information based on analysing relevance of the projects undertaken by them (even in future).

Stage 3b: Propose Innovative Solution

After completing the Literature Review (or at times during the review process) students are asked to propose a solution to the problem identified in the previous step (and recorded in the project plan) based on their improved conceptual understanding on the topic. This step ensures that students have clear and feasible strategy to deliver an innovative solution at the end of the research project. It is very important that students are strategically aligned to deliver a good quality innovative solution (could be a process, product service, argument, feasibility report, etc.) and also to prove the improvement by comparing with existing knowledge in the literature.

The students are asked to update section of their project plan (left blank previously) with the proposed solution including methodology, interpretation and validation of results which is reviewed by the mentor.



Stage 3c: Apply and Validate Solution

Students further progress in their research by following the project plan to deliver the proposed solution. They conduct experimentation (e.g., surveys, stimulations or in labs using equipment) and apply their understanding into new situations. This cross application of concepts for solving practical problems allows them to demonstrate correlation between having a qualification and doing well in higher education and workplace. The experimental results are validated by student by comparing it with the existing knowledge in order to demonstrate superior quality. The students are asked to document the application and validation of their solution to a prevailing problem.

CRE program trains school students to deliver quality innovations from an early stage. It is this superior quality of innovation by research practise that will help expedite growth of India into an economic powerhouse.

Stage 4: Abstract Submission

Depending upon the innovation and its field, a suitable conference in India or abroad is identified by the mentor for submitting the research work of the student (the work may also be submitted to a peer-reviewed journal for publication). Students are asked to prepare abstract for submission to a conference. They are able to clearly summarise their research work in few words due to their experience in creating snapshots of the research articles by Active Reviewing.

An Abstract is around 300 word summary of the students research project. It provides very brief outline on the project background, gap in knowledge, proposed solution, analysis, results, and validation and benefits of the research and/or practical applications of the innovative solution delivered through the research. The mentor reviews the abstract, asks the student to electronically submit the abstract.

Stage 5: Full Paper Writing

Students acquire technical writing skills throughout the research process. They acquire it by developing a project plan, regularly preparing Active Reviews and documenting the research at every step. This documentation not only helps the mentor in monitoring the progress made by the students throughout the CRE training, but also provides plenty of already available materials, prepared by the students in their own words, ready to be converted into a formal piece of technical writing, *also known* as The Research Paper. This formal document is reviewed by the panel of international subject area experts.

Stage 6: Conference Presentation

The acceptance of research paper by the expert panel set-up by the body organizing the conference, provides student the invitation to attend and present the work to global audience of experts. The students are tested for the authenticity and originality of the research work, and the expert audience from around the world authenticate whether the work has been done by the students *by asking various questions* related to the research paper. The paper of the student eventually gets published as a permanent piece of innovative contribution to the knowledge and helps drive India's ranking to the top in the Global Innovation Index.

Presenting research work at international conferences is not only prestigious, it also boosts the morale of the students and increase their engagement with academics. The opportunity they get to meet and interact with the thought-leaders and experts at the conference, help students capture a true snapshot of the career they are dreaming for in the future. Moreover, networking with the thought-leaders and experts beyond the conference, could earn them a valuable letter of recommendation for entry into the world leading institutes (often with a scholarship) as these leaders have already experienced the quality of students work and potential to perform excellent in the future endeavours.

REFLECTION ON CRE TRAINING INTRODUCED AT INDUS WORLD SCHOOL

The new CRE program was hello introduced at the Indus World School in Indore (India), in the academic calendar 2016-2017. A total of 35 students, from classes 9th to 12th, were selected for the CRE training. Although, students have only undergone eight months training so far (with four months of training remaining), but they have shown tremendous improvement in terms of acquiring new 21st century skill set. This section discusses on how the CRE training has added value in the students and improved their profile.

Value Addition: Representative Case Studies of Conceptual Research Experience

This section discusses on how the CRE training has added value in the students using different case studies.

Case 1

A 9th grade student is an avid tennis player who has represented her school at several inter-school and district level competitions. Obviously, this girl is very interested in sports. However, can we use her interest



in tennis to raise her academic profile? Can we help her create visible example of her learning by blending sports and academics? Can we help her demonstrate transferable skills in-life after school?

The 9th grade tennis player was present at the research seminar conducted at the school. She became curious and asked a question – My clothes smell terrible after the tennis game, I want to make self-cleaning clothes. But, how? Research is the answer said the presenter, Why don't you solve this yourself and find the answer? I can mentor you. She was delighted! After the session, she submitted the short essay on question for which she was looking for an answer, and post 1:1 web session, she was selected to the CRE training program.

The student started the research process, read review papers, prepared the project plan, wrote Active Review for every reading she conducted and identified the proposed solution that Silver nanoparticles and titanium dioxide nanoparticles can be used to kill bacteria and produce self-cleaning tennis jerseys.

She has designed a robust process to produce self-cleaning jerseys and is currently writing the research paper. As a student, she feels more engaged with her studies, has acquired a better view of her career-plans, and is confident that she will have an extraordinary profile to demonstrate when seeking admission in a higher educational institute. This tennis player is looking forward to presenting her research findings at an international conference and networking with thought-leaders in her area of interest.

Case 2

Grade 11th commerce student is passionate about Sarees (an Indian ethnic wear for females) but she is very concerned about the poor conditions of weavers. She wants to combine her education and passion to improve the economic condition of weavers in India.

She used CRE training to study the entire system and value chain of Saree production in India and identified that the current system of gaddidars (or middlemen) is inefficient. She found that the current processes forced weavers into perpetual poverty and the weavers are not receiving the rightful share of profits.

In order to put weavers into advantage, she studied online sale model of Sarees and their limitations. This 11th grade commerce student has developed a unique B2C business model so that people can buy Sarees directly from the weavers. Her work will be submitted to a Business Plan Competition, for raising seed fund to start a social venture and improve the state of weavers.

Apart of her research findings will be published as conference proceedings, to aid policymakers in bringing social reforms and changes in the policy. She is a perfect example of future leader who wants to improve the society by her skills, arts and knowledge and contribute in the development of Indian economy.

Case 3

This gifted 11th grade Science stream student who has always been fascinated by the stars and the universe at large has picked up one of the hottest and latest topics in Astronomy – Gravitational Waves. The discovery of Gravitational waves has excited scientists all over the world. Gravitational Wave astronomy has immense potential to give us a peek into the secrets of the Universe.

The student learnt about the latest methods of detecting Gravitational Waves and their limitations. She is currently exploring and coming out with new potential methods to detect faint signals of Gravitational waves. She is looking at the potential drawbacks of the eLISA project and is also looking at the feasibility of inter planetary Gravitational detectors. The paper that she is writing also looks at the potential applications of Gravitational Wave astronomy ranging from discovering the origins of the Big Bang to discovering extra-terrestrial life. She is planning to present her work at an International conference. She is a perfect example of an ambitious STEM student whose horizons have been broadened by being exposed to cutting edge science, which is normally out of the bounds of the school syllabi.

Case 4

Two grade 9 students have focused their research work on e-learning and the feasibility of extending this mode of learning to government schools. Government Schools in India not only lack the proper infrastructure but most of them also suffer from absenteeism of teachers. In such a dire situation, e-learning solutions could be a potential remedy.

The students learnt about the pitiful situation of most government schools in India and found that one major obstacle to improving the system was the absence of teachers. They learnt that the teachers in government schools were not only mostly unqualified but also did not turn up for work every day.

They looked at e-learning in government schools to bridge this gap. However, a huge question was whether students could effectively learn from pre-recorded educational videos. In order to find out the answers, the students carried out a series of experiments in which they tested the learning outcomes of their juniors with both traditional teaching and e-learning; and compared the subsequent results. They are currently compiling their results in to a paper and will communicate it to a conference shortly. This is a perfect example of students taking the initiative to solve problems around them, provided that they are sufficiently exposed to such issues.



Principal's Reflection on CRE Program run at the Indus World School

Conceptual Research Experience training program has been one of the most enriching experiences that few of your students had during past few months. The students were engaged in authentic learning comprising selection of real world issues to serve as research topics for their projects. Initially, the students took little time to get oriented to this new idea but within no time they were able to think flexibly and apply their novel skills. They started taking control of what and how of their own learning.

The interest of students vested in achieving those learning goals was seen to be much higher in their chosen projects than the projects which were assigned to them by someone else. Their mentors and facilitators provided them the criteria, planning, timelines, resources and support to reach their goals. The students are using all their skills to find responses to their own doubts and questions. One can see their confidence and their belief in their work. All students have become so comfortable with the complexities of the undefined problems and to deal with ambiguity and put into practice the higher order skills.

Value Addition: By Student Skills

Table 1: Addition of 7 Surviving Skills of 21st Century in Students through CRE

Skills Acquired	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6
Curiosity & Imagination	YES	YES	YES			
Critical Thinking & Problem Solving	YES	YES	YES	YES	YES	YES
Agility & Adaptability		YES	YES	YES	YES	YES
Accessing & Analysing Information		YES	YES		YES	
Effective Oral & Written Communication	YES	YES	YES	YES	YES	YES
Collaboration across Networks & leading by Influence	YES	YES	YES	YES	YES	YES
Initiative & Entrepreneurialism	YES	YES	YES	YES	YES	YES

Table 2: Learning & Innovation Skills (based on P21's Framework) acquired by Students

Skills Acquired	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6
Creativity and Innovation	YES	YES	YES	YES	YES	YES
Critical Thinking & Problem Solving	YES	YES	YES	YES	YES	YES
Communication	YES	YES	YES	YES	YES	YES
Collaboration		YES	YES	YES	YES	

Table 3: Information, Media & Technology Skills (based on P21's Framework) acquired by Students

Skills Acquired	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6
Information Literacy		YES	YES		YES	YES
Media Literacy						YES
ICT Literacy	YES	YES	YES	YES	YES	YES

Table 4: Life & Career Skills (based on P21's Framework) acquired by Students

Skills Acquired	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6
Flexibility & Adaptability		YES	YES			
Initiative & Self Direction		YES	YES			YES
Social & Cross-Cultural	YES	YES	YES	YES	YES	YES
Productivity & Accountability		YES	YES	YES	YES	YES



Value Addition: Intellectual and Innovation Assessment of Students

Table 5: Modes of Intellectual and Innovation Assessment of Student in the CRE program

Skills Acquired	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6
Interview	YES					
Project Plan		YES				
Active Review			YES			
Documentation			YES			
Innovation				YES	YES	
Conference Presentation						YES
Publication						YES

DISCUSSION AND CONCLUSION

Imagine our pride and admiration when our students, all of just 12-17 years of age, from India take the stage and show case their original, novel research at international conferences in front of world renowned domain experts in areas as diverse as Nanorobots to gravitational waves to pesticide regulations. The young innovator gets a platform to interact with the best of the best role models in his field and realize the essence of the journey to become that world class scientist, economist, teacher, doctor or entrepreneur.

The response of students, teachers and principal to the on-going CRE program has been very positive. Students are able to acquire key competencies of the 21st century. They have not only improved their comprehension, writing and compute ability, but have also acquired new set of skills as shown in Tables 1-4. Addition of new skill set would not have been possible without CRE program within the current education ecosystem. CRE has made students more engaged with their areas of interests, passions and school studies.

CRE provides skills, knowledge, expertise and support systems that students need to acquire to become successful leaders, workers and global citizens of tomorrow. The early stage opportunity to explore their interests and passions helps them raise their profile, plan their career wisely and become more productive citizens of India. However, in order to embed Innovation culture among students, schools must motivate their students to take the first baby step of being an innovator through Research-based Learning.

Private schools in India will play a very crucial role in raising young innovators who develop new processes, products or services of social or commercial value at an early stage. This is because the decision to implement a new program rests with the Principal (or Committee/Trust/Society) running the school, in contrast to the Government schools where multiple entities are involved, the process is lengthy and also time consuming. It is easier for a private unaided school to introduce Research-based Learning as a part of the school curriculum because they enjoy the flexibility of creating their own curriculum by the Indian Government. On the other hand, aided schools can easily introduce a Research-based Learning as new Club (similar to cricket/dramatics/science club/ work experience class) for raising young innovators and driving Innovations in India.

Another important factor which makes the role of Private Schools very important within the Indian Innovation Ecosystem is that, when considering only the secondary and higher secondary school segments, enrolments in private schools account for 63% of the total in contrast to the Government schools which have low student/parent interest. Since, private schools in this segment account for 56% of the total schools in India, they are ideally suited to provide early-stage Research and Innovation experience to large number of Indian youth, improve learning outcomes of the students and develop linkages to higher education and industry for transfer of student knowledge and skills to the next level.

Therefore, it is imperative that our corridors of education, that is Schools which are second home of the children, rise up to the occasion and play their role of developing young individuals with an Innovation mindset. Only then can we, as a nation, expedite our growth to becoming one of the largest economies globally by leveraging Innovation as a key driver for growth.

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