

Implementation of STEM Education in Schools

Prof. Sunethra Karunaratne



Introduction

We are living in the 21st century. The world is changing rapidly with the advances of science and technology. We cannot continue the practices that we have used in the past to be successful at present and in future. It is our responsibility to prepare the present generation to meet the challenges of the future. UNESCO has introduced four major skills that are required to be successful in the 21st century. They are:

- Collaboration
- Communication
- Creative thinking and
- Critical thinking

Attle and Baker (2007) have shown that 80% of all employees work in group settings. Employment in modern day require transferable multidisciplinary knowledge and skills. Employers value effective oral and written communication skills as well as the ability to work effectively within diverse groups (Finelli et al. 2011). They have found that new recruits find it hard to get adapted to working situations in their institutions due to a lack of critical-thinking skills, and the

ability to communicate effectively, solve problems creatively, work collaboratively and adapt to changing priorities. In addition, they have not developed “soft skills” and also “hard skills” related to specific jobs. Most countries such as USA, UK, Australia, Singapore, Malaysia, and Canada have identified this gap during the last few decades. They have identified that by improving the knowledge and skills in mathematics and science will immensely contribute to improve creative and analytical skills of persons. They have consequently planned to deviate from the conventional way of teaching mathematics and science, and have aimed to provide a broader understanding that may

help to integrate these disciplines with technology and engineering. Thus they have stepped out from the conventional box of education, and tried to improve creative and analytical thinking among students and youth by introducing

fun learning methods. Many countries plan to improve achievement in STEM (Science, Technology, Engineering and Mathematics) education to bring about a workforce leading towards improving economy and sustainable development, by preparing children to meet global challenges of the modern world such as energy, health and the environment.

Knowledge structures of STEM education

Although there were massive STEM education reforms in USA, Kelly and Knowles (2016) state that implementation has not been successful in integrating STEM subjects in an authentic context, because of the lack of



Fig 01 : Use of robotics in learning

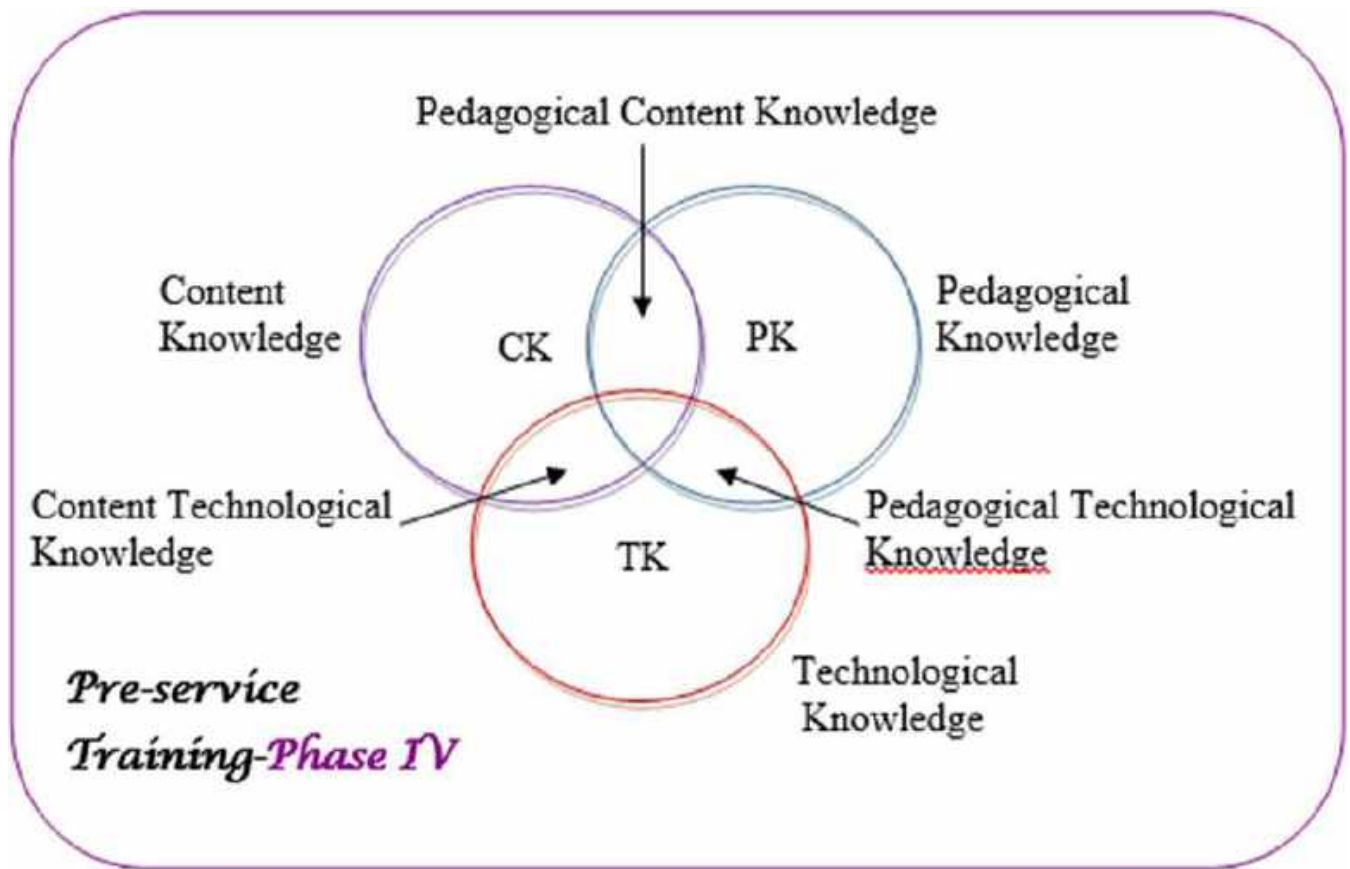


Fig 02 : Integration of content knowledge, pedagogical knowledge and technological knowledge

cohesive understanding of STEM education among educators, and have suggested the need for the formulation of a STEM conceptual framework. This framework needs to be based on learning theories and pedagogies that will lead to achieve key learning outcomes. Integration of STEM requires a strong conceptual and professional foundation on how students learn and apply the STEM content. To help understanding science meaningfully, the learner should place the science concept in a broader and a deeper context to see how science is linked with other disciplines, not only with technology, engineering and, mathematics but also with other disciplines such as Aesthetics (STEAM), language, social studies and, with the use of Robotics (STREAM).

Teachers need to possess a very good understanding of scientific concepts (content knowledge.) They should also possess a sound knowledge on how to teach for a better understanding (pedagogical knowledge). There should be a blend of these two knowledge structures (Pedagogical Content Knowledge, PCK) to help students build up science concepts without misconceptions. In addition they need technological knowledge to craft challengeable activities to arouse curiosity and creative thinking of students to search for solutions. Figure 02 shows how the integration of knowledge structures overlap in the engagement of different activities. In classroom situations, especially in building models, students have to integrate content knowledge with technological knowledge.

Learning becomes interesting if students can see some relevance to what they experience in day-to-day life. Then they can make sense of what they learn, and also they will be able to make connections. Solutions to real life problems are found by bringing several disciplines together and integrating these within the solution. The knowledge gained by studying one subject is not enough to find a solution to a real world problem. As Nadelson et al. (2012) state STEM education teachers require a pedagogical content knowledge (PCK) to help students to make sense of what they are learning, and to apply these to real world contexts.

Table 01 : Energy lessons from Grade 1 to Grade 11

Grade	Subject Area
Grade 11	<ul style="list-style-type: none"> ▶ Energy and energy generation ▶ Power ▶ Heat ▶ Electricity ▶ Magnetism
Grade 10	<ul style="list-style-type: none"> ▶ Work ▶ Energy ▶ Power ▶ Energy transformation ▶ Energy uses in daily life
Grade 9	<ul style="list-style-type: none"> ▶ Simple machines ▶ Power input ▶ Power output ▶ Efficiency ▶ Levers
Grade 8	<ul style="list-style-type: none"> ▶ Electricity ▶ Electric circuits ▶ Efficiency ▶ Sound waves ▶ Magnetism
Grade 7	<ul style="list-style-type: none"> ▶ Energy forms ▶ Measuring energy ▶ Efficiency ▶ Practical uses of energy
Grade 6	<ul style="list-style-type: none"> ▶ Energy ▶ Energy forms ▶ Practical uses of energy ▶ Energy saving
Grade 5	<ul style="list-style-type: none"> ▶ Force ▶ Work
Grade 4	<ul style="list-style-type: none"> ▶ Simple machines
Grade 3	<ul style="list-style-type: none"> ▶ Work
Grade 2	<ul style="list-style-type: none"> ▶ Magnetic forces
Grade 1	<ul style="list-style-type: none"> ▶ Pull ▶ Push ▶ Light

Role of teachers in implementing STEM education

To bring about a skillful generation, teachers have to play a bigger role. In order to do proper planning, teachers need to understand how concepts are included in the school curriculum, and how these are connected from the previous grade to the current grade and to the next grade. They will be able to organize the content under several themes, so that students will build up concepts related to the theme in a progressive way from grade 1 to grade 11. This is vertical integration. In a STEM education workshop for teachers held in the Central Province, in collaboration with the Central Province Education office and the Postgraduate Institute of Science (PGIS) (December 14-15, 2019 at PGIS) they were asked to identify how the content is organized in the current syllabus. Table 1 shows how a group of participants drew up vertical integration for the “Energy” theme. In the oral presentation they suggested how to revise it to get a deeper understanding of the concepts as the students go from grade one to eleven. They showed how mathematics, technology and, engineering could be linked in teaching.

It is also necessary to have horizontal integration with other disciplines. In STEM education practices it is the key factor. Successful implementation would be possible if parallel grade teachers plan lessons together. It is also necessary that the other teachers who teach language and social studies to participate in this discussion. By sharing their

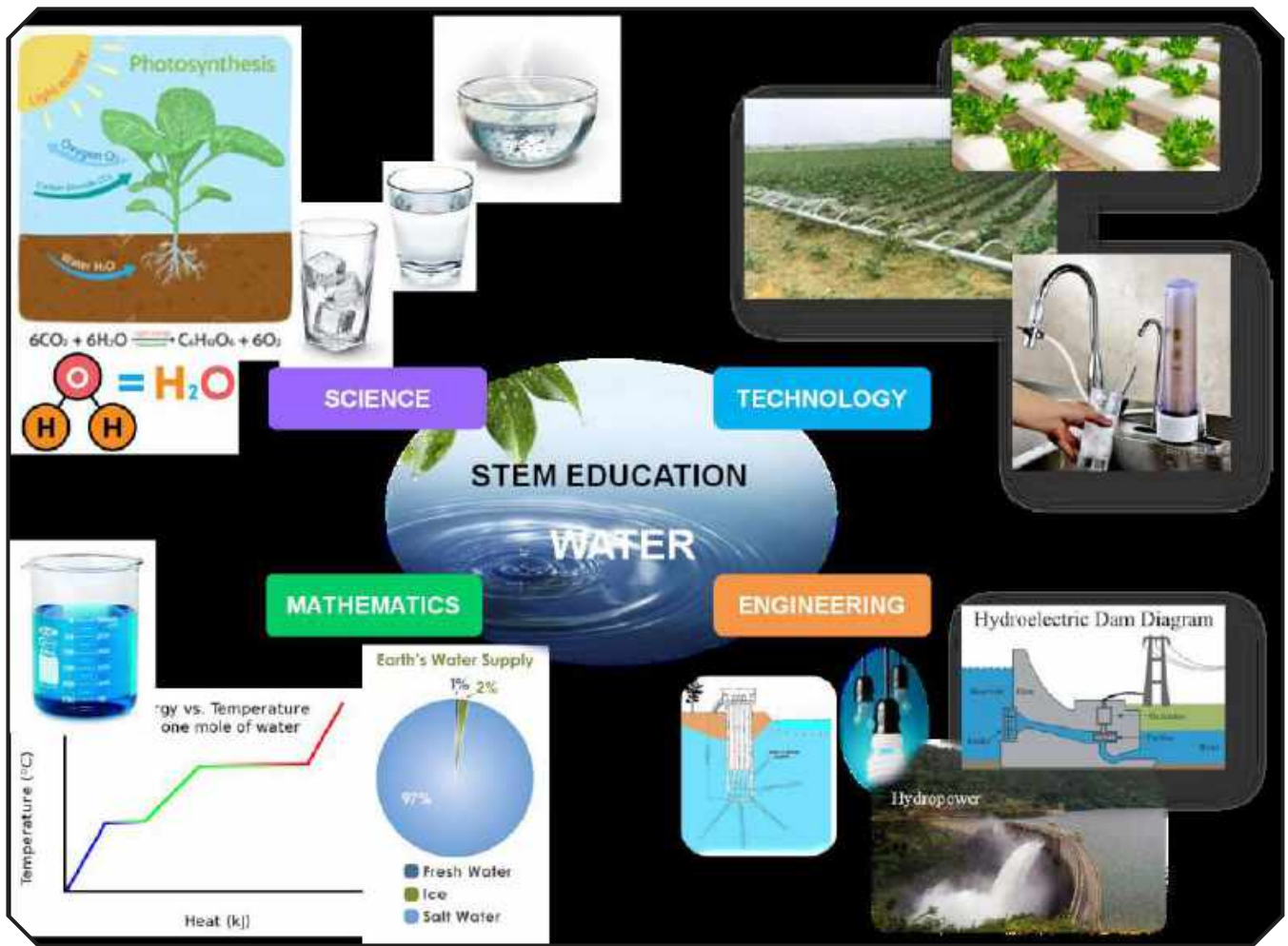


Fig 03 : Horizontal integration in teaching “Water”

experiences so many bright ideas will emerge in linking examples from other disciplines. Figure 3 shows a possible horizontal integration in teaching “Water.” For science we generally present

the properties of water, chemical formula and the reaction to represent formation of water and the uses of water. We need mathematics to present, size, capacity of water bodies and relationships of variables graphically. Technology has been used to design several efficient ways of applications of water in agriculture, health and purification. Use of engineering demonstrates the

construction of massive projects such as power plants, dams and hydroelectricity.

Groupwork

In STEM education practices assigning groupwork is essential. Sharing the benefits of groupwork with the students in a transparent manner helps them understand how learning could be improved and prepare them for life experiences (Taylor 2011). Creating facilitated opportunities for groupwork allows students to enhance their skills in working effectively with others (Bennett & Gadlin 2012). Groupwork gives students the opportunity to engage in process skills critical for processing information, and



Fig 04 : Students working in groups to solve a problem



Fig 05 : Students' engagement in groupwork

evaluating and solving problems, as well as management skills through the use of roles within groups, and assessment skills involved in assessing options to make decisions about their group's final answer.

Johnson and Smith (2014) found that students learning in a collaborative situation have greater knowledge acquisition, retention of material, and a higher-order of problem solving and reasoning abilities than students working alone. There are several reasons for this difference. Students' interactions and discussions with others allow the group to construct new knowledge, place it within a conceptual framework of existing knowledge, and then refine and assess what they know and what they do not know. This group dialogue helps them to make sense of what they are learning and what they still need to understand or learn (Ambrose et al. 2010).

In solving a problem, group members need to share their experiences and propose ways of solving. The collaboration and communication among the members help in thinking creatively and critically to arrive at a solution with consensus.

Groups can tackle more complex problems than individuals and thus have the potential to gain more expertise and become more engaged in a discipline (Qin et al 1995). Groupwork creates more opportunities for critical thinking and can promote student learning and achievement.

Conclusion

At the initial level teachers might find it difficult to use different teaching methods and strategies, but with collaborative lesson planning, it is easy to make links with other subjects by using the following methods in the teaching learning process, such as:

- Problem-based learning
- Project-based learning
- Role play
- Drama
- Posters
- Panel discussion
- Debate
- Quiz programmes
- Computer programming
- Developing models

All these methods could be used as groupwork to enhance skills of collaboration, communication, cooperation, creative thinking, critical thinking, problem solving, innovative and designing, social responsibility and ethics, leadership and, adaptability to live in a multicultural society. Students are required to gather information from home, community and other institutions and, through surfing

internet to complete the given task, to solve the problem in an effective way and to share with the whole class. Teachers are required to assess students continually based on the engagement of work. The entire methodology of teaching is student-centred and based on a constructivist approach.

Education reforms are geared towards economic development. Although economic development is important, ever increasing GDP without any care to other aspects of life and nature is unsustainable and can inadvertently sabotage happiness. The Gross National Happiness (GNH) philosophy in Bhutan is development guided by human values (National Education Framework, 2012). The educational initiative, "Educating for GNH" is a teaching learning process functioning in all schools to develop critical thinking, teamwork, values and many other skills such as peace. Another key priority is the implementation of "Transformative pedagogy or 21st century pedagogy." It is a comprehensive set of teaching strategies and skills. STEM could be implemented successfully in Sri Lankan schools by paying attention to develop 21st century skills in students with the use of 21st century pedagogy by teachers.



Prof. Sunethra Karunaratne
 Retired Professor in Education
 0717259303
 0776259303
 sunrank@yahoo.com

