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# Fostering the 21st Century Skills through Scientific Literacy and Science Process Skills

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**Abstract**

To overcome the challenges of the twenty first century in science and technology sector, students need to be equipped with the 21st century skills to ensure their competitiveness in the globalization era. They are expected to master the 21st century skills apart of just being excelled in their academic performance. Therefore, it is crucial to incorporate 21st century skills in science education. 21st century skills comprised of four main domains namely digital age literacy, inventive thinking, effective communication and high productivity. Scientific literacy is one of the skills required in digital age literacy. It means knowledge and understanding of the scientific concepts and processes required for personal decision-making, participation in civic and cultural affairs, and economic productivity. Scientific literacy is important in our modern society since they are many issues related to science and technology. Basic science process skills include observing, classifying, measuring and using numbers, making inferences, predicting, communicating and using the relations of space and time. While the integrated science process skills consist of interpreting data, operational definition, control variables, make hypotheses and experimenting. Science students have been cultivated by scientific literacy and science process skills through science classes. With these two skills, it is hoped that the science students have developed some skills needed in 21st century skills. This paper will further explain about the 21st century skills, scientific literacy and science process skills. It also explains about the intersection of science process skills and 21st century skills in science education.



*Keywords:* 21st century skills, scientific literacy, science process skills

## 1. Introduction

The 21st century offers life in a borderless world, globalization, internationalization and the explosion of information and communication technology (ICT) (PIPP, 2006). The rapid development of technology and information dissemination will result in the expansion of knowledge that will impact the economy, culture and politics of a country. Current explosion of information and technology and knowledge-based economy have changed the implementation of the education system. The era of digital economy requires a workforce that is knowledgeable and skilled to generate innovation and improve productivity of a country (NCREL & Metiri Group, 2003; Nur

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Aishah et al;, 2009 : Executive Summary of the Plan-10, 2010). Thus, this 21st century students need to be able to solve various problems by thinking creatively and the use of technology. The education sector is undergoing a paradigm shift in which learning should be changed from horizontal to loop of knowledge that combines knowledge, application and continuous contribution (Kamisah & Neelavany, 2010).

Now the world community in the 21st century has evolved into a new era known as the 'knowledge age' or 'k-economy'. The new requirements emphasize the importance of information, creativity and innovation in providing new services to the community (Alimuddin, 2011). This change also emphasized the need for creative thinking approach; the strategy involves problem solving and global nature of economic activity (Ramlee and Abu, 2004). This information age has allowed every individual to develop their talents and potential through "Technology-powered knowledge" and an opportunity for all parties to pursue lifelong learning. This is the main challenge facing the current generation of students and the future. As such, they should be prepared with not only good academic achievements alone but also 21st century skills that are needed in the working environment in this century (NCREL & Metiri Group, 2003).

## 2. 21st Century Skills

NCREL and Metiri Group (2003) have identified the enGauge 21st century skills which need to be acquired by future generation in order to meet the challenges of globalization due to the advancement of information and technology. There are four main domains specified in the 21st century skills namely digital age literacy, inventive thinking, effective communication and high productivity. The digital-age literacy skills in accordance NCREL (2003) consist of basic literacy, scientific literacy, economic literacy, technological literacy, visual literacy, information literacy and multicultural literacy. Basic literacy means language proficiency (in English) and numeracy at levels necessary to function on the job and in society to achieve one's goals, and develop one's knowledge and potential in this digital age.

Scientific literacy means knowledge and understanding of the scientific concepts and processes required for personal decision-making, participation in civic and cultural affairs, and economic productivity. Economic literacy means the ability to identify economic problem, alternatives, costs and benefits; analyze the incentives at work in economic situations; examine the consequences of changes in economic conditions and public policies; collect and organize economic evidence; and weigh costs against benefits (NCREL and Metiri Group, 2003).

Technological literacy means knowledge about what technology is, how it works, what purposes it can serve, and how it can be used efficiently and effectively to achieve specific goals. Visual literacy means the ability to interpret, use, appreciate, and create images and video using both conventional and 21st century media in ways that advance thinking, decision-making, communication, and learning. Information literacy means the ability to evaluate information across a range of media; recognize when information is needed; locate, synthesize, and use information effectively; and accomplish these functions using technology, communication networks, and electronic resources. Multicultural literacy means the ability to understand and appreciate the similarities and differences in the customs, values, and beliefs of one's own culture and the cultures of others whereas global awareness means the recognition and understanding of interrelationships among international organizations, nation-states, public and private economic entities, socio-cultural groups, and individuals across the globe (NCREL and Metiri Group, 2003) .

Inventive thinking comprises of adaptability/managing complexity, self direction, curiosity, creativity, risk taking and higher-order thinking and sound reasoning. Adaptability/managing complexity is the ability to modify one's thinking, attitude, or behaviour to be better suited to current or future environments, as well as the ability to handle multiple goals, tasks, and inputs, while understanding and adhering to constraints of time, resources, and systems (e.g., organizational, technological). Self-direction is the ability to set goals related to learning, plan for the achievement of those goals, independently manage time and effort, and independently assess the quality of learning and any products that result from the learning experience. Curiosity is the desire to know or a spark of interest that leads to inquiry. Creativity is the act of bringing something into existence that is genuinely new and original, whether personally (original only to the individual) or culturally (where the work adds significantly to a domain of culture as recognized by experts). Risk-taking is the willingness to make mistakes, advocate unconventional or unpopular positions, or tackle extremely challenging problems without obvious solutions, such that one's personal growth, integrity, or accomplishments are enhanced. Higher-order thinking and sound reasoning include the cognitive processes of analysis, comparison, inference/interpretation, evaluation, and synthesis applied to a range of academic domains and problem-solving contexts (NCREL and Metiri Group, 2003).

Effective communication involves five components which are teaming and collaboration, interpersonal skills, personal responsibilities, social and civic responsibilities and interactive communication. Teaming and collaboration means cooperative interaction between two or more individuals that working together to solve problems, create novel products, or learn and master content. Interpersonal skills mean the ability to read and manage the emotions, motivations, and behaviours of oneself and others during social interactions or in a social-interactive context. Personal responsibility is depth and currency of knowledge about legal and ethical issues related to technology, combined with one's ability to apply this knowledge to achieve balance, integrity, and quality of life as a citizen, a family and community member, a learner, and a worker. Social and civic responsibility is the ability to manage technology and govern its use in a way that promotes public good and protects society, the environment, and democratic ideals. Interactive communication means the generation of meaning through exchanges using a range of contemporary tools, transmissions, and processes (NCREL and Metiri Group, 2003).

High productivity consists of prioritizing, planning, and managing for results, effective use of real-world tools and ability to produce relevant, high-quality products. Prioritizing, planning, and managing for results are the ability to organize and efficiently achieve the goals of a specific project or problem. Effective use of real-world tools is the effective use of these tools – the hardware, software, networking, and peripheral devices used by Information Technology (IT) workers to accomplish 21st century work. It means using these tools to communicate, collaborate, solve problems, and accomplish tasks. Ability to produce relevant, high-quality products is intellectual, informational, or material products that serve authentic purposes and occur as a result of students using real-world tools to solve or communicate about real-world problems. These products include persuasive communications in any media (print, video, the web, verbal presentation), synthesis of resources into more useable forms (databases, graphics, simulations), or refinement of questions that build upon what is known to advance one's own and others' understanding (NCREL and Metiri Group, 2003).

Thus, the definition of student's achievements must be broadened to include the 21st century skills that will be required for students to thrive in the future. Students ought to have the ability to apply the knowledge that they have learned to face the challenges of life beyond school. It is a current trend in education where students are able to solve multifaceted problems by thinking creatively and generating original ideas from multiple sources. The sheer magnitude of human knowledge, globalization, and the accelerating rate of change due to technology necessitates a shift in student's education from plateaus of knowing to continuous cycles of learning, applying and contributing (Kamisah & Neelavany, 2010).

## 3. Scientific Literacy

Scientific literacy plays an important role in human daily lives. Promotion of scientific literacy has been recognized as a major goal of science education in the world (BouJaoude, 2002; National Research Council [NRC], 1996; Zembylas, 2002). Educators agree that scientific literacy should be nurtured as early as possible (Barton, 1994; Bybee, 1997). Miller (2002), who has been involved in assessing scientific literacy for over three decades, emphasizes the importance of "civic scientific literacy" in a modern society that relies heavily on technology. He believes that 21st century society requires a public with knowledge about scientific and technological issues for the democratic process to function properly.

Although recently the concept of scientific literacy appears to be the main goal of science education curricular in many countries, there is no consensus on its meaning and content. To define the scientific literacy, many science educators as well as organizations such as National Research Council (NRC, 1996) and American Association for the Advancement of Science (AAAS), draw frameworks, and tried to describe the characteristics of a scientifically literate individuals. NRC (1996) defined scientific literacy as "the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity" (p.22). AAAS (1991) stated in Project 2061 documents that science literacy broadly covers the connections among ideas in the natural and social sciences, mathematics, and technology.

When it comes to actually defining scientific literacy, the discussion becomes more complex. Some metrics focus on facts, concepts, and vocabulary, while other definitions emphasize the scientific process and reasoning skills (SEI, 2006 and Miller, 2006). The science education literature demonstrates that scientific literacy is generally valued and acknowledged among educators as a desirable student learning outcome. Furthermore, what scientific literacy really means in terms of classroom practice and student learning is debatable due to the inherent complexity of the term and varying expectations of what it means for learning outcomes (Veronica et al, 2012). Besides, Pella et al. (1966) in Özdem et al. (2010) in their studies searched for almost hundreds of publications in order to describe characteristics of scientifically literate individual and as a result they stated that an individual who is scientifically literate should have an understanding in "... (a) basic concepts of science, (b) nature of science, (c) ethics that control the scientist in his [sic] work, (d) interrelationships of science and society, (e) interrelationships of science and the humanities, and, (f ) differences between science and technology." (p. 206).

According to DeBoer (1991), the term science literacy was first put forward by Paul De Hart Hurd, a member of the famous science education, in 1958 in an article titled "Science Literacy: Its meaning for American Schools". In the article, Hurd used the term science literacy to clarify the understanding of science and its application to social experience. Meanwhile, Hazen (2002) makes a distinction between being able to do science and being able to use science. He states that "scientific literacy, quite simply, is a mix of concepts, history, and philosophy that help you understand the scientific issues of our times. Norris and Phillips (2003), however, illustrates about science literacy based on a classic analysis of language and philosophy in which science literacy embodies two essential senses: the fundamental sense, and the derived sense. The fundamental sense involves the traditions of being a learned person and the abilities to speak, read, and write in and about science. The derived sense involves knowing the corpus of knowledge in science. The fundamental sense subsumes the abilities, emotional dispositions, and communications of the current standards-based definition of science literacy, while the derived sense subsumes the understanding and application of the big ideas of science in the standards-based definition of science literacy including the unifying concepts of science, the nature of science, the relationships among science, technology, society and environment, the procedures of science, and the social relevance of science.

Based on scientific literacy, as a general definition, should be thought as the combination of both insights related to science and scientific knowledge, as well as skills such as inquiry, critical thinking, problem solving and decision making. This definition requires a scientifically literate person to be able to understand science, the nature of scientific knowledge and the relationship of science with society and environment, to know basic scientific concepts, laws, theories and principles, and to use science process skills. Özdem et al., (2010) & Kyunghee Choi et al., (2011) framework stresses the importance of communication and collaboration, systematic thinking including non routine problem solving, the use of evidence to support claims, and information management within the habits of mind dimension. Students need to learn how to put ideas together and work with others to come up with novel solutions to challenging problems.

Thus, there are a number of reasons why scientific literacy is considered important. The society we live in depends to an ever-increasing extent on technology and the scientific knowledge that makes it possible. We live in a nation with a rich, but not inexhaustible, supply of natural resources. As we live in a world with a rapidly growing population, decisions we make every day have the capacity to affect energy consumption, our personal health, natural resources, and the environment ultimately the well being of ourselves, our community, and the world. Miller (2002), who has been involved in assessing scientific literacy for over three decades, emphasizes the importance of "civic scientific literacy" in a modern society that relies heavily on technology. He believes that 21$^{st}$ century society requires a populace knowledgeable about scientific and technological issues for the democratic process to function properly. Scientific literacy has been recognized as an important characteristic that every citizen in a modern society should possess. In this respect science education which includes 21$^{st}$ century skills is critical for developing students' scientific literacy, which is turn in future scientifically literate citizens.

## 4. Scientific Process Skills

Science process skills can be divided into two, namely the basic science process skills and integrated science process skills. Basic science process skills include observing, classifying, measuring and using numbers, making inferences, predicting, communicating and using the relations of space and time. While the integrated science process skills consists of interpreting data, operational definition, control variables, make hypotheses and experimenting (Curriculum Development Centre, 1993).

Basic science process skills have to be mastered before one can dominate the integrated science process skills. This view is supported by Piaget (1964), students can master abstract thinking in integrated science process skills were provided a complete control of basic science process skills. Science process skills mentioned are one subset of the thinking skills used either by scientist, teacher or student when learning science. Science process skills are used by scientists to investigate and explore and will play a role only when used in the context of science activities such as investigation and interpretation with the scientific understanding (Yeam, 2007).

Science process skills should be utilized by teachers in the delivery of teaching the facts of science effectively. This is because science is not just of knowledge but it is a way to systematically understand the environment. Science process skills are required by students to learn about the world of science and technology in more detail. Students are able to learn science in a meaningful way through an exploration of science process skills based on the constructivist approach (Yeam, 2007). The implications of constructivism for teachers of science teaching and learning is the teacher had to provide the learning environment with hands-on activities that enable students to develop and Master of Science process skills. This is because teachers cannot force students to believe in something other than their own students develop an understanding of the matter (Yeam, 2007).

In teaching and learning of science, science process skills are used as teaching approach. Science process skills are behaviours that promote the formation of skills applied to acquire knowledge and then disseminate what is obtained thus increasing the use of optimum mental and psychomotor skills. This statement is supported by (Djumhur 1996) in Wahidin (2004) who explained that these science process skills can train students in the process of thinking and scientific attitude of the human form. This is because the process of learning and teaching science process skills is a process designed in such a way that students can meet the facts, concepts, and relate to the theory of using scientific process skills and attitudes of the students themselves.

## 5. Intersection of Science Process Skills and 21st Century Skills

In addition to the core of literacy, students also need to acquire research skills. Among other things, they need to know is how to access and book through the library article, note taking and integrate secondary sources, determine the reliability of data, read maps and graphics, visual understanding of scientific, capturing the type of information conveyed by various system representations, distinguishing between fact and fiction, fact and opinion, construct argument and monitor evidence. Students also need to develop technical skills. They need to know how to log on, find information, using a variety of programs, focusing on the camera, edit the recording, do the basic programming and so on (Jenkins, 2007).

According to NCREL (2003), students with scientific literacy knowledge and understanding of science concepts and processes required to engage in the digital era society. Students can ask questions, get, or determine answers queries issued from daily experience. Then they have the ability to describe, explain and predict natural phenomena. Students must also be able to read with comprehension of scientific articles in the popular media and to engage in social discussion of the validity of its findings. In addition, students can identify scientific issues whether at local or national level and provide the scientific and technological information. Students also can assess the quality of scientific information on the sources and methods used to produce it. Apart from that, students should be able to present and evaluate arguments based on the evidence and to produce a summary of the debate is appropriate.

In science process skills, observing is the most basic skill when students doing experiment. They use all their senses to gather information about objects or events in their environment (Monhardt, L. & Monhardt, R., 2006). Through hand-on activities like science experiment, students use different senses by touching, feeling, moving, observing, listening and smelling and sometimes testing materials in a controlled manner. This help students to progress from concrete thinking levels to more complex thinking levels (Jones et al., 2003) which promotes higher order thinking skills in 21st century skills. Other than observing, communicating is also needed in both science process skills and 21st century. Communicating can take many forms including using words, action, or graphic symbols to describe an action or event. It requires students to put information that they have gathered from observations so that it can be shared with others (Bilgin, B., 2006). With good communication skills students will be able to describe the natural phenomena in science class.

## 6. Conclusion and Recommendation

In line with developments in technology and the explosion of knowledge in the digital-age, the 21st century skills can be cultivated through scientific literacy and science process skills especially for science students. Four domains of 21st century are literacy of the digital era, inventive thinking, interpersonal and social skills and productivity in the production. Through the digital age literacy, teachers should be skilled in the use of multimedia technology, such as construction or use of computer software blog. In this way, the aspect of science process skills can be nurtured indirectly through discussion questions through the blog by the teacher to create 'Classroom blog' with the students' community. Next, the method involves learning through animated explanations of scientific concepts and scientific methods, quizzes, activities, virtual experiments, also can increase the capacity of science process skills of students in which students will be able to see clearly how a process occurs through the screen. For example, the process of learning science through animation can be found at website www.brainpop.com, even teachers themselves can build websites that are appropriate in the context of teaching and learning can foster science process skills. The impact of multimedia is that students can explore new concepts that are closer to their daily experience and explaining the concept of good science. This favourable is a change from the way of thinking to a concrete way of thinking. So this could indirectly increase students' interest in learning science process skills, and thus make the learning process more effective. This statement is supported by Najjar (1998) who said that more frequent use of animation in teaching and learning can enhance the learning process better than not using animation.

In addition, the activities of design science competition which involves a group of science students can be conducted during the learning process both inside and outside the learning time. Thus, the teaching of Problem Based Learning, known as PBL can also be applied. Next, presentation conducted by students and teachers acting as facilitator can test students' abilities to describe the science process skills through questioning session. Question and answer session between the teacher-student, helps to enhance students' interpersonal skills and soft skills. They can be formed in addition to attract students to use their science process skills. Indirectly, inventive thinking can also be applied to the student. According to Orhan Akınoğlu and outlook Özkardeş Tandoğan (2007), this PBL method has been found to encourage the development of students' conceptual. Consequently, their findings showed that students will better understand the practical principles of chemical science, through the transfer of knowledge to the problems in daily life. Furthermore, a positive attitude towards learning science itself can be nurtured and thus teamwork and social interaction could be improved.

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