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Understanding the Challenges of Science Education in the 21st Century: New Opportunities for Scientific Literacy

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ABSTRACT

This essay examines the challenges of science education in the 21st century with regard to social, cultural, economic, political and pedagogical issues impacting and influencing instructional methodology and understanding of the role of science education as it affects individual, social organizational and societal progress and functions. Drawing upon some strong practical, philosophical, and pedagogical-methodological and theoretical ideas and propositions from Hodson, as espoused in his book *Looking to the Future*: *Building a Curriculum for Social Activism*, the author essentially responds to this extremely rich scholarly volume in scientific literacy, philosophy, and history by supporting Hodson's advocacy of *an action-oriented and issues-based curriculum* as the key to renewing and activating scientific literacy to increase students' performance and national competitiveness in the global economy. The author extricates from literature, not only strong rationale for the renewal and transformational of science education in terms of perspective and approach, but also takes a critical approach in examining some of Hodson's contentions regarding strategies in confronting socioscientifc issues as major pathways to the teaching and learning of science. The author examines problems, challenges, and the new opportunities that have emerged and are emerging in contemporary environmental, social, cultural and political contexts for science education to experience transformation in several ways: as a field of study, as an applied body of knowledge, as a way of living and as a competitive tool and strategy important to national goals and posterity.

***Keywords*:** science education, scientific literacy, curriculum, social activism, issues-based curriculum, action-oriented, environmental problems, mono-methodology, globalization, nature of science (NOS), nature of technology (NOT), philosophy of science (POS), socio-scientific issue (SSI).

1. INTRODUCTION

The need for explicit teaching has sharpened efforts to understand what knowledge and skills teachers need in order to engage youngsters in effective learning in the science classroom [22]. More and more scholars from various fields are recognizing the importance and impact of science education, as well as the current and emerging challenges and opportunities to science education. One such expert is Derek Hodson who is Emeritus Professor of Science Education at the Ontario Institute for Studies in Education (University of Toronto), Adjunct Professor of Science Education at the University of Auckland, and Visiting Professor of Science Education at the University of Hong Kong.

The scholarly-academic rigor, scope, intellectual fervor, richness in thoughts and ideas, and the philosophical adeptness of his book *Looking to the Future: Building a Curriculum for Social Activism* attest to his breadth and depth of knowledge and experience, as well as his expertise in Science Education. The book focuses on Science Education and builds upon some of Hodson's previous works representing culminating intellectual activism for better understanding of, and increase in scientific literary, improved methods in science education, and the development of a more realistic and action-oriented approach to science education. Hodson [19] impresses upon an audience of educators, policymakers and administrators, the need to re-engage and redesign curriculum to make Science Education more formidable and useful as competitive value and solution to our myriad problems.

Hodson's book provides more than a framework for redesigning science education and science literacy programs because it reflects similar calls by other science education experts to make science literacy an action-oriented approach in building curriculum for social change and activism. Science education in the 21st century must focus on developing strategies and solutions to our common problems, and in doing so, must consider the importance of approaches built around collaboration and participatory pedagogy. We are living in a global society where diversity impacts on science call for a variety of perspectives and appreciation of the different learning needs and methods that students and citizens use to understand science even at the most basic level as it unravels in nature. There emerges a necessity to change our understanding of the approach to science literacy as educators, as we recognize that the platform for applying its body of knowledge has changed and is constantly changing.

We are living in a world where science itself must adapt and thus, we ourselves, especially teachers and educators of the discipline must immediately recognize that we are not teaching a static discipline. We must therefore broaden our own horizons as new knowledge and ideas emerge to replace and add credibility to those we have held on to as the correct way, while recognizing that some ideas become obsolete. Science literacy requires recognizing that learners have responsibilities for their own learning and creating opportunities and strategies for self-experience to become part of formal classrooms. For this to happen, science teachers or educators must understand the rationale and elements of science literacy to apply and promote new paradigms in a borderless classroom called the global environment.

2. SCIENCE EDUCATION: PARADIGMS, ELEMENTS, AND RATIONALE

The first of a multiplicity of conceptual frameworks for Hodson's work is laid down in what he describes as the four major elements of science education: (a) *learning science*: acquiring and developing conceptual and theoretical knowledge; (b) *learning about science*:

developing an understanding of the nature and methods of science, appreciation of its history and development, awareness of the complex interactions among science, technology, society and environment, and sensitivity to the personal, social and ethical implications of particular technologies; (c) *doing science*: engaging in and developing expertise in scientific inquiry and problem solving, and developing confidence in tackling a wide range of "real world" tasks and problems; and (d) *engaging in sociopolitical action*: acquiring (through guided participation) the capacity and commitment to take appropriate, responsible and effective action on science/technology-related matters of social, economic, environmental and moral ethical concern [19,20].

These four elements of science education provide a framework upon which science educators can develop an approach to science that makes scientific learning more practical and action-oriented as part of the current paradigm shift in the relationship between humans and their environments as evident in an increased tendency toward consumer environmentalism, the green revolution and sustainability movement impacting economic and political actions and activities across the globe. The four major elements of science education described by Hodson [19] not only represent foundational knowledge and the most practical approach to science education philosophy, but reflect the trends and building block themes that constitute most of the focus of science education today. For example, Abell and Lederman [1] approach the summation of the body of knowledge constituting science education and literacy in contemporary contexts using five themes that encompass these four elements: (i) Science Learning; (ii) Culture, Gender, and Society and Science Learning; (iii) Science Teaching; (iv) Curriculum and Assessment in Science; and (v) Science Teacher Education. Overlapping these themes is the idea of promoting a public understanding of science, something Hodson [19] views as invaluable in the current paradigm shift that provides opportunities for increasing scientific literacy.

Hodson [19] refers to this rationale of scientific literacy in terms of "why we need it and why we should promote [it]" (p. 2). This will always remain fundamental to questions on scientific literacy and Science Education for individuals, schools, and society. Hodson presents the rationale of scientific literacy categorized under three groups of arguments proposed by Thomas and Durant [23]: (i) perceived benefits of science, (ii) benefits to individuals, and (iii) benefits to society as a whole ([19], p. 2). In order to be successful in imparting science knowledge and literacy, science educators must provide this rationale for the teaching and learning of science so that their pupils can appreciate the applied significance of science to both individual and societal progress and survival; we need science because it is vital to both individual and societal progress and survival. Science literacy is an integral part of our individual and collective search for purpose.

3. APPROACHES TO SCIENCE LITERACY EDUCATION

In a similar light to Hodson's recognition of the importance of science education in the global economy and the salient factors affecting science literacy and learning opportunities and challenges, Ash and Klein [2] recognize that the mediums for learning science and promoting scientific literacy are not limited to the formal academic or classroom setting, but can be found in what they call the "informal learning environment". This supports Hodson's idea of action-oriented science instruction based in understanding and applying learning experiences and encounters in the real world or daily environment to understanding the methodology and process of science. Hodson [11] is merely echoing a call to action which has long been posited by science educators and science learning theorists for the last two decades; the need for a more involved-and-activity-based practical approach to scientific literacy. Bailey and Watson [3] communicate to us an assessment of strategy based on drama role in ecological learning as a viable approach to the development of scientific understanding and learning in younger pupils. Furthermore, Barraza [4] points to the importance of children's creativity as a source for energizing and motivating interest and learning in science education based on the supposition that children's drawings about the environment are essential to their learning and understanding of science. In fact, this method of science learning is an old method lost to computer technology and the easy availability of graphics and graphic software to replace the natural element of human-hand drawn figures and symbols of science. For example, an essential part of learning human anatomy or general anatomy and physiology was to be able to draw and label bodily structures and parts accurately, even demonstrating chemical and other process flows. However, computer animation, graphic software and other photographic technologies have virtually eliminated that approach in the majority of science learning classrooms at all levels.

Participatory pedagogy as espoused by Barrett [5] is another essential variable of the kind of action-oriented curriculum that Hodson [19] proposes as an instrumental approach in seeking to renew and better scientific learning and literacy in the 21st century. Barrett [5] believes that a participatory pedagogy in science facilitates the kind of interaction vital to efficient teaching and learning in science. As such, science educators have a great responsibility in ensuring that learning is not a process of dominating and dictating, but one which gleefully and creatively engages students' motivation and desire to know and apply what they learn to daily life. Science should be taught as an active and true-to-life discipline far from what the science fiction dramas on television and in Hollywood communicate. Science is real and focuses on the realism and reality of progress and survival relative to individual and societal experiences in contemporary settings. Participatory pedagogy demands student-teachers' inquiry-based actions addressing issues that are socioscientific and which underpin the human and technical elements of science learning as a field [9].

Instructional contexts for students' science learning must be carefully designed. In order for this to happen 21st century, science educators must understand student work and learning habits as this is a key factor in being able to design supportive instructional contexts [10]. This may require revisiting the root of pedagogical content in science education [11] and observing trends in the contemporary global environment to see how well old methods of instruction integrate vital learning constructs and ideas. It is always the responsibility of the science educator or teacher to make sure that curriculum and the instructional methods being used to teach science are up-to-date. This reasoning stems from the fact that while schools and school districts establish curriculum based on long-term goals, tactical and short-term changes are best implemented at the classroom individual science teacher or instructor level as they observe immediate changes in the global environment and incorporate them as evidences and examples into their instructions. For example, natural disasters as they occur will alter understandings and plans regarding learning needs and strategies based on how much they impact regions and people. This needs to become part of science and scientific processes at work and the science teacher is the one who must incorporate changes to accommodate understanding of such phenomena in time contexts.

Birdsall [12] believes that an important aspect of teaching science in 21st century democratic and capitalist oriented societies is to "empower students to act" by teaching them how to learn about the nature of science (NOS) by doing and through action observed in nature. This is part of what Hodson [19] describes as action-oriented approach to science learning. This requires recognizing that students can and should be encouraged to learn science in their everyday lives as there are numerous contexts outside of the classroom wherein students can learn about science [13]. This requires adopting a learner-centered pedagogy [14] which recognizes that students must be responsible learners in science.

Students must be taught how to think constructively about science [15], recognizing that science literacy is an integrative and required body of knowledge that coordinates ideas about technology and society's education as integral to individual survival and cooperation as functional members of their communities and the global community.

4. THE PROBLEMS AND CHALLENGES OF SCIENCE EDUCATION

The United States ranked 29th in science among 57 countries in 2007 based on major report by the Organization for Economic Cooperation and Development (OECD) which measured student literacy in science, math, and reading among 15 years old [21]. While the United States ranked 29th behind countries like Croatia, the Czech Republic, and Liechtenstein, and ahead of just nine other OECD countries, the top country in science education was Finland [17]. Scores in science and mathematics for eight graders were much better when the United States ranked 11th in science and 9th in mathematics according to The Trends in International Mathematics and Science Study [18]. These rankings were still below Asian nations which have dominated in these subjects for several years. There are also other nations with less wealth, resources and technology that outrank the United States in science education and science literacy, and this has led to the United States taking a major role in the promotion of science literacy on a global level. Some of the problems of performance in science education can be traced by to the methodological and instructional approaches to science teaching and learning.

Science has for too long been taught and learned as a mono-methodological branch of knowledge. Only decades after personal struggles with science literacy are some teachers and experts of science education recognizing this as a fundamental problem. This mono-methodological approach emphasized objectivity and empiricism and subjectivity and creativity were penalized in students as teacher-centered approaches to science discredited and deemphasized the kind of participatory pedagogy proposed by Barrett [5] and the creative-arts-oriented [4] and action-oriented [19] approaches. Thus, students' creative and self-devised ways of learning science through daily experiences and associations were not exactly appreciated because the "rigor" of science precluded all other matters in the teacher-centered science classroom right up until the 1990s. As Barrett [5] indicates, participatory approaches to science instruction are not to be perceived as disruptive.

However, teachers bent on instructor-dominated or lecture-method approaches tend to view certain levels of participation in science learning from pupils as interference. This attitude needs to change through the practice of embracing more student-friendly and student-centered approaches in the science learning or science classroom. Thus, teacher development becomes a critical factor in the paradigm shift being promoted in science education [8].

The need to understand the importance and relevance of science as an applied and rational field of study immediately accessible in our most immediate and daily environments should have been a major factor prelude to the introduction of science and its methods and body of knowledge in classrooms. However, many teachers continue to make the error of focusing from the beginning on theories and formulas without establishing the raison d'être of scientific literacy and knowledge to individual personal growth and development and to society. Bartholomew, Osborne and Ratcliffe [6] argue that:

> Pupils should appreciate that science is an activity that involves creativity and imagination as much as many other human activities, and that some scientific ideas are enormous intellectual achievements. Scientists, as much as any other profession, are passionate and involved humans whose work relies on inspiration and imagination (p. 657).

This need for creativity cannot be overemphasized, especially as science education increasingly becomes a competitive factor among nations in the education arms race and economics arms race of the 21st century. Bartholomew et al [6] certainly understand the role of human passion, inspiration and imagination as part of teaching and learning whether it is in science or art. Humans are social creatures and we are socialized into our roles through culture and social interactions from birth to death. Thus, it is only natural and even inherent that our passions and imaginations become the ultimate tools and sources of learning in all we pursue, whether science or art.

One of the major challenges of science education in the 21st century is to re-orient the teaching-learning practices to focus on science as “an art” of acquiring scientific knowledge rather than as a rigid and cold method of knowing about our environment, selves and the processes operating at various levels to constitute life processes and affect our survival and ability to use and tame nature and its attributes. Science has for too long been taught as a form of dead poetry. In earlier years of the 18th and 19th centuries, science teachers and learners used their creativity, passion and desire to know and understand as the major factors in fueling scientific rationale.

The nature of science (NOS) was not seen as so separate or contrary to the nature of art or literature, but rather a complementary body of knowledge wherein profusive learning was both appreciated and valued. Thus, science and scientific learning fell within the scope of integrative teaching and knowledge acquisition. As technology and mechanization and automation became dominant processes across industries however, the rigorous quantitative indices relevant to performance driven financial and economic units brought about a decline in the diversity of science methods in education.

Thus, the globalization and commodification of science [7] has been a significant factor in the changed treatment of science as part of an integrative whole in curricular knowledge requirements in schools and society. Science does not need to respond to globalization as a laboratory problem, but as a new frontier or platform consisting of diverse elements and particles.

5. NEW OPPORTUNITIES IN SCIENCE EDUCATION

Living in a global community, we must begin to treat science education as what Cobern [16] describes as “an exercise in foreign affairs” (p. 287). Today, the world is more multicultural and socially integrated than any other times in history and the convergence of people and culture provides numerous and new opportunities for learning and development in science education and literacy never before encountered. Science becomes more valuable as a process and body of knowledge in explaining connections and interconnections between people and between man and nature as we converge with new and unique powerful technologies to affect the planet and its landscapes. Additionally, science provides rationale in the contexts of global collaboration, negotiation and cooperation and collaboration among nations and regions.

Most of the new opportunities for teaching science or advocating and improving scientific literacy on individual and societal levels stem from needs and challenges arising in the global environment where environmental problems, the green revolution, sustainability movement, and the increased difficulties faced in meeting social and economic welfare call for greater cooperation and understanding of what can be called our common universal needs and challenges.

The new opportunities to teach science education in the 21st century global environment arise in several specific fields or areas which Hodson [19] outlines in his book: human health, land, water and mineral resources, food and agriculture, energy resources, industry in power and waste disposal, IT and transportation, and ethics. These areas encompass the major challenges and problems that emerge in an increasingly complex and chaotic world where science literacy and education is playing a major role in developing solutions and motivating actions. Hodson [19] believes that the political-legal factors driving globalization trends and ideals are centered on these seven areas, and as such, they are the areas on which science curriculum for promoting and achieving educational and economic changes need to focus. These political-legal factors operate to address a variety of socio-scientific issues and challenges that require us to make decisions at various levels that will impact the human journey.

Over the last two decades tremendous changes occurring at lightning speed have impacted our planet and these changes affect our abilities to provide and maintain human health, the availability of land, water and mineral resources, food and agriculture supply and availability, the shifting and decline in energy resources use, the recycling industry and IT and transportation to meet the needs of all. Additionally, the ethical problems and challenges we face have increased within various corners of this globally converging environment and science can find new opportunities to address these through innovative inventions and ideas. However, science itself is responsible for most of these ethical dilemmas, especially those associated with human and animal life and genetic and other experimentations.

The global contexts of modern society in which science education unfolds is the ideal setting in which Hodson's action-oriented and issues-based curriculum can be realized by applying his 3-phase approach: (i) modeling – the teacher demonstrates and explains the desired behavior, and provides illustrative examples; (ii) guided practice – students perform specified tasks within an overall action strategy with the help and support of the teacher; and (iii) application – students function independently of the teacher (p. 103).

This 3-phase approach advocated by Hodson as part of an action-oriented and issues-based science curriculum takes into consideration the participatory pedagogy of Barrett [5] and the empowerment approach of Birdsall [12] as student-focused instructional approaches to promoting science literacy. Scientific literacy is not only a response to need for improvement in general human conditions and situations, but is highly needed to respond appropriately to nature's furies and to the many problems and challenges that emerge from our actions and behaviors.

Science creates and destroys and its creative powers are needed to respond to those who would engage its body of knowledge to destroy what we know as life and social order. From natural disasters to terrorism and medicine, science is one of the most useful and important disciplines in changing our world and the way we live, learn, play and think.

6. CONCLUSION

Science is a field of study, an applied body of knowledge, a way of living and a competitive tool and strategy that is not only important to individual, but to national goals and posterity. However, to realize the great advantages and benefits of scientific literacy and education, we must be able to impart the appropriate ideas, attitudes and knowledge to students and regular citizens. The best arm through which science literacy can be nationally administered is the power of administrative agencies in education and environment as developed and funded by the state. Regardless of how much funding and governmental participation are involved in science literacy and education, what will matter tremendously are the curricular and instructional methodologies and structures that are designed, implemented and effectuated at the classroom and school levels. Teachers of science therefore have a great responsibility in ensuring that students understand and appreciate the nature of science (NOS) as they have appreciated the nature of technology (NOT) and its values.

Numerous and longstanding attempts at educational reform in the United States and other nations to improve student performance and school effectiveness have not focused extensively on a science paradigm as the bedrock of transformation. Such a paradigm would require redefining the philosophy of science (POS) to include a new understanding of science in the context of human affairs as they impact survival in a decisively global economy of contracting resources. Thus, instructional methods and the body of knowledge constituting science must be reconsidered to incorporate strategy as part of the need-based response to contemporary problems to which the field can be applied as a body of knowledge. This means that the mono-methodological approach to science education described above is no longer viable in today's world and that problem-focused and practical ideas need to play a major role in science literacy education.

Revisiting science literacy to construct a new paradigm is recommended on the basis that we are living in a globally diverse society where diversity of scientific thinking should be encouraged and should dominate as a widely accepted perspective in a knowledge society.

Bartholomew, Osborne and Ratcliffe [6] support this idea of "Diversity in Scientific Thinking" by arguing that "Pupils should be taught that science uses a range of methods and approaches and that there is no one scientific method or approach" (p. 657). This is really radical thinking when it comes to consideration on the objectivity, empiricism and traditional methods of science education. However, this is required because technology is so widespread that the label of "science" and title of "scientists" and emergence of new inventions are not restricted to the formally educated scientifically literate individuals at the forefront of the discipline in our society.

Another important recommendation for contemporary science education is for teachers of science and science curriculum planners to view science as a consensus-building discipline as it can be used to bring together people from diverse backgrounds and cultures with diversity of scientific thinking to make science learning a team and collaborative effort. Bartholomew, Osborne and Ratcliffe [6] understand this and argue for cooperation and collaboration in the development of scientific knowledge in individuals based on the idea that:

> Pupils should be taught that scientific work is a communal and competitive activity. Whilst individuals may make significant contributions, scientific work is often carried out in groups, frequently of a multidisciplinary and international nature. New

knowledge claims are generally shared and, to be accepted by the community, must survive a process of critical peer review (p. 658).

Science and science literacy and education must play their part in developing solutions and strategies to meet common problems that we all face and this can only be achieved if science is advocated as a communal discipline rather than as the “mad-isolated scientist” vocation generally depicted as practiced within a confined environment such as a laboratory or some secret basement. Pupils must be taught that science is essentially life and its processes in action. These processes involve those generally regarded as and constituting social actions and value consensus that must lead to resolving issues that fall within the nature and scope of science. Thus, action-based curriculums for social activism as advocated by Hodson [19] engender this concept in the very act of people coming together to respond to and confront socio-scientific issues (SSI).

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