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INTER-DISCIPLINARY APPROACH: A TOOL IN UNDERSTANDING THE NATURE OF SCIENCE

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Abstract *- School students are naturally curious about their expanding possibilities. They are bound to figure out who they are and where they belong in the world. Many students also think that the world they look at through the classroom window is distant and unconnected to the world of chalk boards and pop quizzes they inhabit between hours they spend in school (Duerr, 2008). According to George et al. (1992), an effective school atmosphere balances depth with breadth and provides experiences that help students become more connected to their environment. Teaching method that embraces a mix of traditional and modern ideas that accommodate students' eagerness for individual choices, for first-hand experiences and for varied learning contexts should be what is in place in each classroom setting.*

Current reforms in science education emphasize teaching science for all, an ultimate goal of developing scientific literacy (Bell, 2008) which can be achieved through understanding the very nature of science. However, it is observed that in most cases, in an effort to condense complicated topic into a single unit, the nature of science is somehow lost. Ross (2013) argues that in order to promote understanding of nature of science in the classroom, an approach that integrates sciences and humanities can increase students' exposure to science concepts by relating them to the students' interests and knowledge.

In this view, science must go beyond simply teaching science as a body of knowledge. Teachers are now challenged to engage students in learning science in a much-broader sense—how scientific knowledge develops and evolves and the very nature of knowledge itself.

An emerging viewpoint emphasizes that a thorough understanding of today's real-life problems requires interdisciplinary reflection. For example, in trying to solve for a heavy traffic in EDSA requires a lot of consideration from environmental, social, economic and political point of view all included in the bucket list when trying to solve such a complex issue. A truly interdisciplinary approach requires what professors and students find the common ground in order to make the connections across disciplines and not to isolate them. Prominent psychologist Howard Gardner (1983) established that students bring multiple forms of intelligence to the learning process. As a result, given that students are heterogeneous in their learning styles and have diverse learning backgrounds, interests, talents and values, he believes that drawing a broad array of frameworks and methodologies will enhance students' engagement, and thus have significant learning (Fink, 2003).

In this review, analysis was done on how inter-disciplinary approach had been conducted in featured cases and how helpful had it been to teaching and learning. It also sought to connect the link between IDA and understanding of NOS as a barometer of promoting scientific literacy. Likewise, strengths, issues and downsides of the approach were also looked into.

Keywords: Interdisciplinary approach, Nature of Sci

Introduction

The science classroom is an obvious venue for promoting understanding of the nature of science but usually is taught with deadening litany of facts that describe the natural world with significantly aiding students understanding of the nature of science as a process of inquiry with a distinct methodology.

Identifying effective means for teaching the nature of science (NOS) has become a central focus for science education in the recent years. Studies have shown that, among children, adults, science teachers and even scientists, the understanding of the NOS is meager at least (Smith and Scharmann, 2008). NOS seem to be neglected despite the many developments in the teaching of science. This is becoming especially important in the light of recent developments in pedagogy, as for example, more teachers adopt constructivist methodologies and computing technology which enables similarities that may blur the lines between models and reality (Thye and Kwen, 2004).

During the past 85 years, almost all scientists, science educators and science education organizations have agreed on the objective of helping students develop informed conceptions of nature of science (Adb-El-Khalick, Bell and Lederman,1998; Duschl, 1990; Meichtry, 1993). Presently and despite their varying pedagogical and curricular emphases, there is an agreement among the major reform efforts in science education (American Association for the Advancement of Science [AAAS], 1990, 1993; National Research Council [NRC], 1996) about the goal of enhancing students' conception of NOS.

In the Philippines, the consistent result of Third International Mathematics and Science Study (TIMSS) provide lessons for assessing our manner of delivering science education in the country. The absence of science culture is often cited as the major factor in the low achievement in science. Nebres and Intal (1998) pointed out that the country is still a traditional society that adjusts to, rather than processes the environment. Curiosity and observation, which are important precursors of scientific discovery are not encouraged at home and schools (Ibe and Ogena, 1998). Also, it is common that schools do not nurture science- oriented students except those under special science school curricula. Usually, science is taught in elementary and high school levels as absorption of information in textbooks and the mentor with little or no emphasis with scientific development of knowledge through observation, gathering information and discovery learning. At tertiary level, the introductory science courses do not serve to recruit students into science career. Rather, these courses sometimes tend to be so difficult that students have second thoughts about pursuing further science courses (Nebras and Intal, 1998)

In the history of the study of education, there has been "a conflict between pluralist, eclectic outlook conveyed as 'educational studies' in which disciplines are pre-eminent and a quasi-scientific approach expressed as 'educational research' in which the disciplines are relegated to the margins" (McCulloch, 2002, p. 102). Predominant among those engaged in the study of education used to be the view that "education" is not a single discipline but a field of applied research to which different academic disciplines contribute (Moichiro, 2014). However, with the present form of education, interdisciplinary approach can be unsatisfying. Therefore, an ideal form of interdisciplinary approach in the education grows out as a sophisticated awareness of the developmental dimensions of human living and our world. In this picture, each academic discipline is self-standing and, at the same time is a part of a larger endeavor to make sense of human living and the environment in which we live.

What is Inter-disciplinary Approach (IDA)?

Inter-disciplinary approach entails the use of integration of methods and analytical frameworks from more than one academic discipline to examine a theme, issue, question or topic. The hallmark of interdisciplinary education is integration on notions and guiding principles from multiple disciplines to systematically form a complete, and coherent framework of analysis that offers a richer understanding of an issue under examination (http://serc.carleton.edu/sp/library/interdisciplinar y/index.html). In this approach, learners interact with the goal of transfer of knowledge from one discipline to another. It also allows learners to inform each other's work and compare individual progress (Phoenix et al, 2013).The approach blends traditional lectures, class discussions, hands-on experiments, site visits to clinics and laboratories and student research. Participatory learning also plays a key role in the approach.

IDA has been defined by Executive Director of the Association for Integrated Studies William H. Newell and William Green (1982) as "inquiries which critically draw upon two or more disciplines and which leads to integration of disciplinary insights (Haynes, 2002,p.17). It is uniquely different from a *multi-disciplinary approach*, which is the teaching of topics from more than one discipline in parallel to the other, nor is it a *cross-disciplinary approach* where one discipline is crossed with the subject matter of another (Jones, 2009).

What is the Nature of Science (NOS)?

As educators, students are aimed to understand the nature of science as a process of inquiry which is defined to include the basic scientific method, how research questions are developed, the role of technology in scientific ideas and research, and an understanding of the implications of science in students' lives as citizens, consumers and hopefully, lifelong learners(Ross, 2014). It is also hoped to demystify how scientific knowledge is created or tested exposing students to working laboratories and scientists.

In general, nature of science refers to the key principles and ideas which provide valid description of science as a way of knowing as well as characteristics of developing scientific knowledge. Apparently, many of the core ideas are lost in everyday science classroom resulting in students learning misconceptions and faulty notions about how science is conducted. Perhaps, the best way to understand the nature of science is to first think about *scientific literacy*. Current science education reform efforts emphasize science literacy as a principal goal of science education (American Association for the Advancement of Science, 1989;1993). However, there is a substantial agreement in the academic community that levels of scientific literacy among the general public are undesirably low even for the technologically-driven societies.

Scientific literacy is the ability to understand media accounts of science, and to be able to recognize and appreciate the contributions of science in decision making on both everyday and in socio-economic issues (Bell, 2008). 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 helps you understand a scientific issue of our time". With no question, scientific literacy is the prime driver for better understanding of science and to enable every citizen to participate effectively as citizens in modern societies.

NOS is a convergence of set of ideas that are most viewed in practical school setting and potentially most useful in developing scientific literacy (Adb-El-Khalick, Bell and Lederman,1998; Duschl, 1990; Meichtry, 1993). It includes the following concepts:

1. **Tentativeness.** All scientific knowledge is subject to change in light of new evidence and new ways of thinking.
2. **Empirical evidence.** Scientific knowledge relies heavily upon empirical evidence. Empirical refers to both quantitative and qualitative data. All scientific ideas must conform to observational and experimental data to be considered valid.
3. **Observation and inference.** Science involves more than the accumulation of countless observations—rather it is derived from a combination of observation and inference.
4. **Scientific laws and theories.** In science, a law is a succinct description of relationships or patterns in nature consistently observed in nature. A scientific theory is a well-supported explanation of natural phenomena.
5. **Scientific methods.** There is no universal single scientific method. Scientists employ a wide variety of

approaches to generate scientific knowledge.

6. **Creativity.** Creativity is a source of innovation and inspiration in science. Scientists use creativity and imagination throughout their investigations.
7. **Objectivity and subjectivity.** Scientists tend to be skeptical and apply self-checking mechanism such as peer review in order to achieve objectivity. On the other hand, intuition, personal belief and societal values all play significant roles in the development of scientific knowledge. Thus subjectivity can never be completely eliminated from scientific enterprise.

Nature of Science instruction must include IDA

Taking into consideration the findings about student understanding of the NOS, several different approaches for teaching the NOS have been developed. Lederman 1992; Lederman and Abd-El-Khalick1998; Abd-El-Khalick and Lederman 2000; Khishfe and Abd-El-Khalick 2002). McComas et al. (1998) identify four approaches to NOS instruction based on where the instruction is situated: within methods courses, within science content classes, within authentic science experiences (e.g., internships in research laboratories), and within self-contained NOS courses or units. In large part, we hold most claims for any one of these approaches and against the others to be straw-man arguments. Smith and Scharmann, 2006 share the view of McComas et al. (1998) and others that NOS understanding may best be enhanced when students learn informed views of the NOS, not just in one class, but when they encounter mutually consistent views of the NOS across more than one setting.

Alternatively, Abd-El-Khalick and Lederman (2000) distinguish between implicit and explicit approaches to NOS instruction: Implicit NOS instruction assumes that students can learn the NOS by ‘‘doing science.’’ Students engage in science-based activities, but NOS issues are not specifically addressed. In contrast, explicit NOS instruction takes NOS learning to be a direct target, not a side effect of the learning experience. Aspects of the NOS are directly addressed with students. In keeping with a constructivist view of learning, explicit instruction has typically included extensive opportunities for students to reflect on their understandings of the NOS and how the readings, lectures, or other learning activities impact those understandings. According to Abd-El-Khalick and Lederman (2000), the difference between the two types of instruction lies in the extent to which learners are provided (or helped to come to grips) with the conceptual tools, such as some key aspects of NOS, that would enable them to think about and reflect on the activities in which they are encouraged.

Although there has been no research to date directly comparing the two modes of NOS instruction in a single study, the weight of the available evidence from numerous studies of programs that employed one or the other clearly favors explicit reflective NOS instruction over the relatively ineffective implicit mode for developing NOS understanding (Abd-El-Khalick and Lederman 2000).

Research studies have employed a wide variety of materials and methods for use in explicit reflective NOS instruction, including reflective journal writing, small and/or large group lectures and discussions, teacher questioning, science-embedded activities, card sorts/card exchange games using NOS concepts, concept mapping, analysis of critical and typical teaching incidents, presentations by visiting expert speakers (scientists, philosophers, historians of science, classroom teachers who teach NOS, etc.), debates, readings, videos, developing lesson plans that address both science content and NOS, historical case studies, and comparing positions of philosophers, historians, and sociologists of science (McComas 1996). The primary question arising from this literature, of course, is: How effective have these attempts been at promoting an informed understanding of the NOS among students?

Effective school balance depth with breadth and provide experiences that help young people become more sophisticated and holistic. A teaching method that embraces a mix of traditional and modern ideas and accommodate students' eagerness for individual choices, for first-hand experiences and for varied learning contexts (Goerge et al. 1992) that is the very nature of interdisciplinary approach must be cultivated in our educational system.

Research questions:

The review focuses on answering the following questions:

1. What are the characteristic of interdisciplinary approach?
2. What are the strengths and weaknesses of interdisciplinary approach?
3. What are some research claims/findings on interdisciplinary approach in educational setting?
4. How does interdisciplinary approach promote understanding of NOS?

Methodology

In this review, model IDA-based activities were included to give flesh to the nature of the approach as well as to derive relevant information as to how the approach was effective in making students understand the nature of science. Likewise, student and teacher perception on the approach was presented in the following cases:

Cases/issues where IDA is applied

Case 1

Sample activity integrating interdisciplinary (problem-based learning) approach in the classroom (Redshaw & Frampton, 2014)

Task: Marine Harmful Algal Blooms (HABs)

Investigation on the potential harm of algal blooms relevant to environmental and human health issues in a certain lake.

The involvement of the following is required:

a. Biology in understanding species present
b. Chemistry to understand water treatment
c. Toxicology is required to interpret impacts upon human health and knowledge of public health
d. (Responsibility of) government organizations and legislation

Observations on the approach:

1. Overcoming issues of different levels of skill within group work is difficult heterogenous grouping).
2. Providing forums where all disciplinary perspectives can be addressed and consolidated must be looked into.
3. It increases opportunities for further meetings/ group work, thereby enhancing peer learning
4. It gives students more structure which will help to overcome feelings of needing steering, or not understanding the purpose of the activity. It may also prevent individual from dominating project direction/parameters.

***Case 2** Sample course integrating interdisciplinary approach (Ross, 2014)*

Theme: Body Clocks (Chronobiology)

Disciplines involved: Biology, Psychology and History

Phases

Phase 1 Segmentation of Professors

Phase 2 Integration of faculty material and weaving a cohesive course syllabus

Phase 3 Professors contributed several lectures in each unit, providing bridges to connect gaps

In each unit, fundamental questions about how scientists develop questions, test hypotheses and draw conclusions. Weekly faculty meeting was conducted to discuss what worked and what did not and how topics can be integrated in the next unit.

Some significant unit highlights:

1. Biological, psychological and historical approaches provided students a way of understanding the

topic as a body of knowledge that is highly relevant to the lives and interests of the students:

Biology Professor discussed the biology of circadian rhythms and the neurological phases of sleep (brain anatomy, role of pineal gland and regulatory hormones and chemicals in the sleep cycle)

Psychology Professor discussed the actions of common sleep aids and the physical and mental effects of sleep deprivation.

History Professor discussed how student understanding of sleep changed over the course of the 20th century underscoring technological breakthroughs like EEG and discovery of rapid eye movement or REM.

By linking the diverse topics, students were able to understand the biology of sleep, apply what they have learned to their own lives and form ideas about how technology can shape scientific research

Other relevant activities that reinforced the material covered in lectures and readings:

1. Hands-on learning activities (Perception of the concept and passage of time)
2. Clinic visit (how data on sleep disorders are collected and evaluated)
3. Visit to Army Aviation research center testing pilot performance under various conditions, including sleep deprivation.

For non-science majors, the site visits were especially invaluable introductions to working laboratories and real scientists. Students met researchers, asked questions, viewed equipment, saw real-world examples of how circadian rhythms are studied and why, and discussed how such research is funded. They were able to encounter science as an active process and laboratories as sites of knowledge production, rather than science as simply a body of knowledge disconnected from human actions and buried in textbooks. This aided in their understanding of the nature of science, and therefore, the acquisition of scientific literacy (Ross, 2013).

Student research comprises 20% of their course work. Findings were presented in a university research conference. Students were involved in all stages of the scientific inquiry such as formulating the research questions and hypotheses, developing questionnaires and other tools, collecting and analyzing data and presenting their results. These practical experiences aided their understanding of the nature of science in ways that more typical science instruction does not. For the non-science majors, the experience was unique in their science education (Ross, 2013).

Case 3

3.1 Chemist Willard Libby who discovered radio carbon dating applied his findings in Chemistry to the discipline of Archaeology. Youngblood (2008) says Libby's technique is a great foundation for interdisciplinary studies but a true IDA should go beyond Libby's technique.

3.2 Youngblood (2008, p.3) highlights Newell's demonstration of a geographer who is involved with a team that tries to solve the problem on acid rain. Newell says "In order to be successful, she may find it just as necessary as will the practitioner of interdisciplinary studies to develop an understanding of issues ranging from chemistry to culture".

Benefits of Inter-Disciplinary Approach

The benefits to students are worth the investment of time required for interdisciplinary courses and greatly outweigh the costs. Successful curriculum integration and interdisciplinary approach allow learners to see wholeness rather than fragmentation (Duerr, 2008). They can also confront questions and engage in experiences that are personally meaningful to them (Manning and Bucher 2005). IDA encourages critical thinking skills and creativity of both teachers and students and a fresh outlook on teaching method. It is a worthwhile approach toward making learning more effective for all students.

In a study done by Boyer and Bishop titled "Young Adolescent Voices", 77 students from three middle schools were asked what they thought about their IDA program. Boyer and Bishop (2004) found IDA not only had a positive effect on students learning, but also inhibited personal growth. Students learned tolerance for their peers as well as leadership and collaboration skills. Study found that the majority of students found the experience beneficial and that the students spoke of long-term relationships and of a democratic learning environment that honored their voices and empowered them as learners. Youngblood (2007) states that IDA is beneficial because on discipline cover physical and social sciences as well as humanities as they focus on considering interrelations between realms of knowledge. Staples (2005) explained that Environmental Sciences need IDA due to the poor state of environmental education and the need for improvement in ecological literacy (2005,p.6).

IDA is the key to interdisciplinary success not the domain of subject material or textbooks alone. Interdisciplinary techniques are not only important for a student to learn any one single discipline or solve problem in a systematized manner, but it also enriches a students' lifelong learning habits, academic skills and personal growth (Youngblood & Duerr,2008)

As educators, we should seek to enlighten our students as to the value of interdisciplinary approach that embrace and celebrate different scientific paradigms, ensuring teachers do not indoctrinate them within a singular paradigm, but allow them to become genuinely interdisciplinary scientists, regardless of the teachers' background and doctrines (Phoenix et al., 2013).

The Downside of Interdisciplinary Approach

The benefits of IDA are not without their disadvantages (Jones, 2013). Rahul Kanakia (2007) author of the article "Talk about benefits of interdisciplinary approach, as well as some pitfalls" quotes Donald Barr as saying "professors who focus on interdisciplinary studies isolate themselves from the core of their field". In contrast, interdisciplinary focus on the fringes of a field, which lowers the academic reputation in the eyes of his peers and hurts his chance for tenure. Interdisciplinary approach is undoubtedly challenging even for the most experienced educator, due to conflicts between disciplines in terms of their differing and often opposing epistemologies and ontologies (Kessel et al.,2009) which can result in different vocabularies, attitudes, techniques and even views of reality (Bracker & Oughton, 2006; Jacos & Frickel, 2009). Interdisciplinary units are time consuming to create and require teachers to know their students on a developmental as well as a needs-based level (Duerr, 2008). Interdisciplinary activities require careful planning and review of the grade-level standards, learner characteristics and teacher objectives. Planning alone requires coordinating and collaborating with other grade-level faculty and subject area specialists in the school.

Bintz et al. noted that the biggest concern include scheduling students and dealing with time and space constraints (2006). According to Szoztak (2007),faculty members within IDA generally identify themselves primarily in terms of a particular interdisciplinary theme or questions, rather than with interdisciplinary itself.

IDA via scientific method promotes understanding of NOS

After the study was conducted by Ross et al., (2013) on Chronobiology, the very nature of IDA that students appreciated was the "diversity" of information as the strongest feature with "different perspectives". This was also evident in class discussions where students easily draw information from different lectures and readings to examine the science of body clocks. Student essays on unit exam also revealed the same observation. Separate fields were used to to examine science as a process of inquiry, emphasizing how the science of chronobiology developed alongside the facts of chronobiology. The students clearly recognized the connections which indicate their development of scientific literacy.Through IDA, science and non-science majors develop a new understanding of how the process of science worked or even a new interest in science. Ross et al., (2013) observed one student commented that the course explained "the scientific process" in a new way and another that he or she "learned how to conduct an experiment properly and follow through with it". Students also commented on the value of the research projects as they were able to experience approaching different fields of study. It also allowed them to experience what it is actually like to perform a research experiment and present it to their peers. Based on the assessments, the researchers believe that students successfully learned about the scientific method and the role of experiments in knowledge production. Student research is invaluable in attaining science literacy among the students. Ideally, students should be involved in each step, developing research questions and methods, collecting and analyzing data, and presenting their findings. Through student research, non-science majors in particular gain a much better understanding of the nature of science. Through lectures, active learning, research projects and site visits, students learn about the nature of science and develop a sense of how science is actually practiced. Students employed the basic scientific method, learned how scientific knowledge is generated and debated, and gained an understanding of the implications of science in their lives.

Conclusions

IDA can be meaningful, engaging and educational for students who seek to internalize their learning experiences while developing lifelong learning skills. It encourages critical thinking skills, the creativity of both the students and teachers and a fresh outlook on teaching methods. It is a worthwhile approach toward making learning more effective for all students, specifically non-science majors who gain more appreciation of the approach as it increases their awareness and understanding of the very nature of science. IDA is time consuming and takes serious collaborative teamwork which is an exhausting disadvantage but in the end, the approach promotes many favored skills and will result to understanding nature of science and ultimately improve their scientific literacy.

Recommendations:

1. Educational setting should promote IDA as it provides avenue to create an atmosphere of scientific literacy among learners.
2. Carefully planned and articulated inter-disciplinary activity must utilized as an effective tool in providing a more holistic view of learning environments to the learners.
3. Involve locally available resources in ID-based activities for learners to see the interconnectedness of his/her environment.
4. To promote understanding of the nature of science, train learners to be investigative by probing simple science problems and or lead them to do a science research work.

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