Development of Science Research Culture in Basic Education: A Theory Generation

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Abstract

Science research culture in basic education can be associated with science investigatory projects (SIPs). In relation to this, the paper establishes a theory on the development of SIP culture in basic education utilizing theory generation through axiomatic deductive approach based on steps prescribed by R. Padua (personal communication, November 17, 2014) which creates the theory that basic education institutions contribute to high productivity in SIPs. Simply because humans and non-human resources along with quality Science instruction are needed to yield such productivity. These attributes, resources, and Science instruction foster SIP culture. These are crucial aspects as schools capacitate students and teachers, produce the SIPs, and eventually disseminate these projects in science fairs.

Keywords: basic education, deductive-axiomatic theory generation, science investigatory projects, science research culture

1.0 Introduction

Science research is considered a fundamental tool for national development and progress (DiChristina, 2014; Rull, 2014). As a primary tool for development, science researches have yielded many significant products in emerging fields, such as medicine, biotechnology, and nanotechnology (Rull, 2014), while these researches contribute to the improvement of living standards and progress of humanity in general (Maqbool et al., 2014). Due to their vital role, the country promoted science researches by enacting the Republic Act 2067 or the "Science Act of 1958". Furthermore, science researches are considered crucial in the present and the future. Its vitality is highlighted in the 2017-2022 Philippine Development Plan (National Economic and Development Authority, 2017), Fourth Industrial Revolution (Dadios et al., 2018), and ASEAN Integration (Adriano, 2014). To achieve the goals of science researches, the promotion and conduct of these researches are cascaded to the government, the private enterprise, and the academe.

Recent trends in the Philippines show that the government research initiatives are geared towards human development and citizen welfare, while the private initiatives are focused on advancements in technology and medicine (Albert et al., 2015; Olvido & Sanchez, 2017). In the academe, the Commission on Higher Education (2009) mandates higher education institutions (HEIs) to do research, generate knowledge and technology, and produce high-quality outputs, advance scientific learning, enhance life quality, and promote national development. Some HEIs have been conducting researches and producing quality outputs for a long time, making research part of their academic life. As a result, these institutions may have developed a culture of research.

Research culture happens when research is uniformly expected, discussed, produced, and valued by the academic community members (Hanover Research, 2014; Iqbal et al., 2018). Faculty members develop beliefs and norms that support the consistent conduct of research and product of quality outputs, intending to teach and help the general public (Hill, 2002; Roxas-Soriano et al., 2020). Teachers play their part in research culture when attributes are present, and resources are available, which interact in internal and external dynamics (Salazar-Clemeña & Almonte-Acoste, 2007; Dacles et al., 2016; Mirasol & Inovejas, 2017; Sherab & Schuelka, 2019; Olvido, 2020). In the process of attaining research culture, HEIs pass through development stages. Polk (1989) related research culture development within the clinical perspective, occurring in three phases: birthing, bonding, and stabilization. Similarly, Muhajir & Rahman (2013) compared such development with tree planting, highlighting the processes of creation, growth, development, and nurturing. Olvido (2021) simplified these stages into gestation, expansion, and maturation, especially in teacher education.

Science research culture shares the same dynamics and development stages as other research cultures (Canti et al., 2021). Basic education institutions (BEIs) may develop a science research culture because of science investigatory projects (SIPs). According to the Science Education Institute of the Department of Science and Technology, SIPs are effective media in promoting S&T consciousness among the students in understanding and appreciating scientific breakthroughs in the general public and improving the quality of S&T in the country (Department of Education [DepEd], 2016a). To encourage BEIs to engage in science researches, DepEd organizes the annual S&T fair where students present their research outputs and compete for certain recognitions (Tortop, 2013; Sanchez & Rosaroso, 2019). Since the inception of SIPs and science fairs by BEIs, a number of schools have become consistent winners in the division level, as well as representatives to higher levels of competition in the regional, national, and even international levels. These schools must have developed a research culture in science in their respective learning environments, which led these BEIs to be recognized in terms of their research productivity.

However, the read literature has not presented or characterized the science research culture in basic education levels. Knowing and understanding the inputs, outputs, and dynamics in and around SIP-winning schools could contribute to both theoretical and practical aspects of science research in BEIs. There is a dearth of scientific studies concerning SIPs and science research culture in basic education. There is also a lack of a framework of how SIPs are conducted by BEIs, as DepEd only provides guidelines of what SIPs are and how science fairs are implemented. Generating a theory on how science research culture is developed ultimately answers the question, "What build an excellent SIP culture in BEIs?" Validation of the attributes, resources, and Science instruction may provide meaningful ways to strengthen SIP implementation in BEIs and promote STEM careers among the students.

2.0 Methodology

The paper utilizes the process of deduction in theory development. The deduction begins with the general principles and ends with specific statements, best used for arguments based on laws and other widely accepted principles (Soifer, 2010; Zalaghi &Khazaei, 2016). Specifically, the deduction process is done through the axiomatic deductive approach to generate the theory on science research culture in BEIs.

The steps that the paper followed are reflective of the axiomatic deductive approach in generating the theory R. Padua (personal communication, November 17, 2014): (1) Choosing the phenomenon of interest; (2) Reading the literature; (3) Brainstorming; (4) Formulating the axioms and propositions; and (5) Theory construction. The last step of the axiomatic deductive approach was to specify the theory generated by relating the propositions with one another. The theory shall be stated in general terms, consisting of interrelated concepts, definitions, and propositions that present a logical view of the phenomena through specifying variable relationships (Kerlinger, 1986).

3.0 Theory Formulation

Axioms and Propositions

Research culture happens when research is consistently produced, disseminated, and valued (Hanover Research, 2014). There are dynamics between what is done and what is produced inside and outside the institution (Olvido, 2020). This research culture considers the community members' perception, thought, and behavior concerning research activities (Hernández Méndez & Reyes Cruz, 2014). The way members perceive, think about, and behave towards research activities, and the extent of their motivation determines productivity, degree of their skills acquisition, and level of their education and training experiences (Hill, 2002; Olvido, 2021). As the stakeholders contribute to the research activities of their community, the educational institution is in the process of developing its research culture.

In science, research culture is seen to be developed vis-à-vis the production of high-quality science. High-quality science is described as rigorous, accurate, original, honest, and transparent. Moreover, scientists viewed four components as essential in producing high-quality science: collaboration, multidisciplinarity, openness, and creativity (Joynson & Leyser, 2015). Furthermore, scientific culture maintains quality science through rigorous scrutiny, honesty, integrity, objectivity, and standard ethical adherence ("Scientific Culture", 2013).

The production of high-quality science may be cascaded to the basic education sector, where the guiding principles of the Science education framework are in coherence with the importance of Science research in society. According to DOST-SEI and the University of the Philippines National Institute for Science and Mathematics Education (2011), eight guiding principles govern the country's science education framework. Among these principles, three directly relate to Science research culture: (a) School science should demonstrate a commitment to the development of a culture of science, (b) School science should promote a link between science and technology, and (c) School science should recognize that S&T reflect, influence, and shape our culture. To apply these principles and attain a culture of science, students should be equipped with knowledge, skills, attitudes, and values in scientific investigations and problem solving through the conduct of Science investigatory projects (SIPs). According to DOST-SEI, SIPs are effective media in promoting S&T consciousness among the youth, in the scientific breakthrough understanding and appreciation in the general public, and the S&T quality improvement in the country (DepEd, 2016a). Through SIPs, students can conduct original work, deepen understanding of science's contentious and problematic nature, and be exposed to hands-on, minds-on, and hearts-on tasks (DOST-SEI and UP-NISMED, 2011; Cuartero, 2016; DepEd, 2016b). Therefore, SIPs are important instruments for basic education students to solve problems in the community and make real-world connections (Autiere et al., 2016).

As essential instruments for S&T development and promotion in the country, basic education institutions are encouraged to integrate SIPs in their Science curriculum and conduct such projects within the school year. To further encourage these BEIs, DepEd organizes the annual science and technology fair where SIPs are presented and competed for recognition (Tortop, 2013). In these science fairs, schools have become consistent winners and usual representatives to further levels. These schools must have developed a SIP culture, which led them to be recognized in SIP productivity.

The annual science and technology fair at the national level recognized the SIP productivity of schools from different backgrounds; may these schools be central, national, science, or private. For example, some schools are recognized for their productivity in life science and physical science SIPs, while others are recognized for their innovations in robotics and intelligent machines. These winning schools are evaluated using criteria consisting of creative ability, scientific thought, engineering goals, thoroughness, skill, and clarity (DepEd, 2017). These criteria correspond to the components essential for producing high-quality science (Joynson & Leyser, 2015; "Scientific Culture", 2013), which makes the outputs superior to the outputs of other schools. Therefore, there is a variation in the performance of schools in the area of SIPs (Axiom 1).

Salazar-Clemeña and Almonte-Acosta (2007) highlighted that institutional attributes and policies play an important role in the dynamics of research culture. These attributes drive the research orientation and productivity of higher education institutions. Similarly, these attributes may push the basic education institutions to let their students conduct SIPs, present these projects in science fairs, and eventually develop a research-oriented culture in SIPs. From Axiom 1, the researcher proposes that there are attributes of BEIs that contribute to the high productivity in SIPs (Proposition 1). These attributes are characteristics inherent to the nature of schools and schools' parts, which are essential elements in the basic education development of SIP culture. Therefore, looking into the nature of schools and factors affecting the schools' drive for students' science research capabilities is important in investigating how SIP culture develops in elementary and secondary schools.

Existing literature on research culture development states that certain attributes in schools contribute to productivity in schools. To do so, the process of research culture development involves planning and process phases, which require components necessary to enhance maturation (Olvido, 2020). These components include time; a strong belief in the research endeavor; faculty involvement; positive group climate, working condition, and organizational communication; faculty development program; research infrastructure; decentralized research policy; research funding; and clear institutional policy for research benefits and incentives (Salazar-Clemeña & Almonte-Acosta, 2007; Dacles et al., 2016). This means that there are components that schools should have to develop the science research culture in basic education, particularly in SIPs.

According to Nuffield Council on Bioethics (2014), the science research culture should support high-quality, ethical, and valuable science. Therefore, the essential components of the research culture are needed. In particular, the institution's administration has a crucial role in research culture building, which facilitates access to material and non-material resources (The Royal Society, 2018). Equally important are the teachers who implement science instruction vis-à-vis SIPs, guide students in the conduct of SIPs, find means to make such conduct possible, and train students for science fairs and exhibits (Mascarelli, 2011; Errabo et al., 2018). Other personnel is seen to be essential human resources in the conduct of SIPs in basic education.

The Intel-International Science and Engineering Fair (Intel-ISEF) highlights the roles and responsibilities of certain individuals in the making of such authentic projects in schools: adult sponsor, qualified scientist, designated supervisor, institution review board, and affiliated fair scientific review committee (Society for Science & the Public, 2017).

Aside from the administration, faculty, and personnel resources, material and non-human resources are needed to conduct SIPs. This group of resources may include the support and prioritization of research by the administration and faculty, as seen in the components of continuing faculty research capability programs, financial reward and merit system, infrastructure, research funding, working environments, and inter-institutional collaboration (Salazar-Clemeña & Almonte-Acosta, 2007; Dacles et al., 2016). Among the material resources essential for SIP-making is the research infrastructure. Such infrastructure includes up-to-date libraries, Internet computer laboratories, and available science laboratories well-equipped with tools, equipment, chemicals, and reagents (Errabo et al., 2018).

The read literature reveals that resources contribute to the SIP productivity of basic education institutions (Axiom 2). In the case of SIPs, institutions are persevering to produce quality outputs in science. However, to attain these quality outputs, quality inputs are needed. These inputs may come from the members of the community who are concerned with SIP activities of the institution (Hernández Méndez & Reyes Cruz, 2014), and from the provision of research units, adequate research services, and facilities for the conduct of SIPs (Salazar-Clemeña & Almonte-Acosta, 2007).

From Axiom 2, the paper proposes that human and non-human resources contribute to the high productivity of SIPs in basic education institutions (Proposition 2). When the administration, teachers, and other personnel give time, effort, and money and work together to produce SIP outputs, such projects are prioritized in schools. When updated and functional facilities are available in schools, then there exists a research infrastructure. Prioritization and infrastructure lead to the conduct of SIPs regularly and pave the way for schools to develop SIP culture.

The conduct of SIPs is reflective of the goals of science in the curriculum. The K to 12 basic education system highlights including content, which gave context to the students' lives and the basic and integrated science process and inquiry skills, which are essential in scientific investigations (DepEd, 2016b). The paradigm shift envisions students to exhibit science attitudes and values to solve problems critically and innovate for beneficial products (DOST-SEI & UP-NISMED, 2011; DepEd, 2016b).

SIPs are project-based tasks, which immerse the students in the research process. The research process involves the identification of the problem, formulation of workable hypotheses, conduct of experimentation, analysis, and discussion of results, and formulation of the conclusion and recommendations (Sambeka et al., 2017). Teachers let the students undergo the process and scrutinize the output of each of the steps. For instance, students are engaged in brainstorming activities to identify their science research problem and workable hypotheses. Then, when students undergo the research process steps with scrutiny and several revisions, they are immersed in a rigorous process.

Science instruction involves acquiring knowledge and skills and the inculcation of values and attitudes essential for the understanding and appreciation of improvement brought about by science (Sheldrake et al., 2017). Science values and attitudes include critical thinking, curiosity, intellectual honesty, inventiveness, objectivity, open-mindedness, responsibility, and skepticism. Teachers need to teach these values and attitudes to the students to draw out the good science inside them, thereby awakening interest to do investigations that can benefit their community.

In other words, Science teaching aims to inculcate to the student's scientific knowledge, skills, values, and attitudes, which are essential in solving problems in the community and finding solutions to improve the condition of the society (DepEd, 2016b). Therefore, teachers will effectively implement science instruction when schools have explicitly included these aims of Science teaching in their respective curricula. Moreover, when there is good Science instruction, schools concretize the aims of Science teaching. This leads the students to do more science investigatory projects, which are of use to the community. Once this happens, a culture of problem solving and innovation is expected. Hence, the quality of science instruction affects SIP productivity (Axiom 3).

A recent study by Sanchez & Rosaroso (2019) revealed that SIP teacher-coaches implement science instruction vis-à-vis the conduct of SIPs through the integration of research skills in scientific method concepts. With this in mind, the study proposes that Science instruction can be designed to facilitate the high productivity of SIPs in basic education (Proposition 3). When Science instruction is designed well to concretize the aims of science, students will understand and appreciate the relevance of science, thereby leading them to do more SIPs that are of use to their respective communities. Once this happens, a culture of problem-solving and innovation is expected. Thus, SIP culture is developed.

Generated Theory

To foster science investigatory project culture, basic education institutions (BEIs) must possess certain attributes that would foster an environment conducive for the said academic undertaking. It must also have human and non-human resources that enable the production of quality outputs. Lastly, teachers in the BEIs should be able to implement Science instruction vis-à-vis SIP instruction. The attributes, resources, and Science instruction are crucial aspects as schools capacitate students and teachers, produce the SIPs, and eventually disseminate these projects in science fairs. Thus, the theory generated shall be called Capacitation-Production-Dissemination Theory of the development of science research culture in basic education.

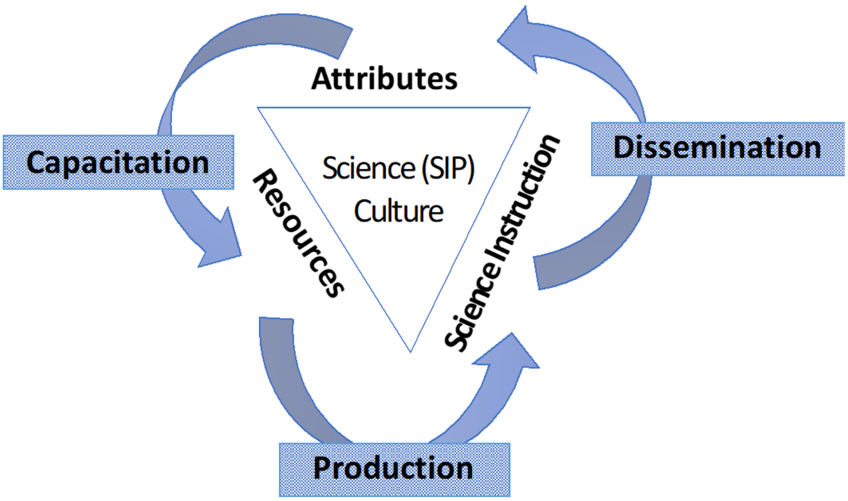

Figure 1. *Capacitation-Production-Dissemination Theory of the development of science research culture in basic education*

Future Directions

As a general methodology for validating the theory, the following tools and processes will be utilized: survey questionnaires (proposition 1) and interviews (propositions 2 and 3). The participants of the theory validation will be the teachers from top-performing schools in SIP competitions. These performing schools are chosen based on their performance in the Regional level science fair based on the archives of DepEd. Once this preliminary phase is done, future researchers will send correspondence to the division superintendents to hold research in their respective jurisdictions. Ethical considerations in the conduct of the study will be dealt with seriously by submitting future studies to the Ethics Review Committee. Data gathering is done through surveys and interviews. Future researchers will analyze the obtained data through appropriate tools.

4.0 Conclusion

Science research culture in basic education is developed through the conduct of science investigatory projects (SIPs). School attributes, available resources, and teachers' Science instruction foster high productivity of SIPs, which involves the phases of capacitation, production, and dissemination in the research culture. Through these phases, SIP implementation will be strengthened in basic education, contributing to the promotion of science aims of the country.

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