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Influence of Teachers' Inquiry Efficacy Beliefs on Students' Scientific Reasoning and Process Skills in Biology

Paula Esperanza Y. Ortha - Polytechnic University of the Philippines College of Science
Rosanelia T. Yangco - University of the Philippines College of Education

ABSTRACT

Teachers' self-efficacy may affect how they teach (Bandura, 1994). Consequently, developing self-efficacy in Scientific Inquiry (SI) is essential as teachers (Dira-Smolleck, 2004). This study then investigates the influence of Science Teachers' Inquiry Efficacy Beliefs (TIEB) on students' scientific reasoning (SR) and process skills (PS) in Biology. It also explored the relationship between SR and PS.

A survey was conducted among 56 Grade 9 science teachers and 1968 students from Quezon City and Manila. Regression analyses suggest that TIEB on Explanation from Evidence may enhance students' skill in identification and control of variables in SR, F(1,1966)=7.902, p=.005, $R^2_{adjusted}$=.004. Linear relationships for the rest of the components were not established. One-tailed Pearson correlation showed a weak, positive link between students' SR and PS in Biology, r(1966)=.21, p=.000, with positive correlations between some SR and PS components.

Students are generally found to exhibit poor abilities in SR (M=22.02%) and PS (M=31.76%) in Biology. Teachers' TIEB score of 3.34 implies a high degree of self-efficacy in implementing SI, possibly a coping mechanism to prevent burnout. Barriers like time constraints were also discussed.

The results imply that the teachers' current SI implementation is not sufficient to influence students' scientific reasoning and process skills in Biology.

Keywords: *biology education, inquiry efficacy beliefs, process skills, scientific reasoning, self-efficacy*

Introduction

Considering the present and emerging social, moral, environmental, and scientific concerns, the Philippines needs to increase its efforts to further educate its citizens. Its democratic system gives the people a collective voice that can change or maintain policies. Thus, a citizen who thinks critically can contribute to the discussion of scientific concerns and make informed decisions for the country (American Association for the Advancement of Science [AAAS], 1993). This vision for a well-informed and responsive citizenry is in line with the goal of the Department of Education (DepEd) when the Enhanced K to 12 Basic Education Program was launched (DepEd, 2010). Through this curriculum, DepEd found it essential to promote scientific literacy through inquiry (DepEd, 2019).

Scientific Inquiry (SI) is defined as the melding of science methods, process skills, and knowledge (Virginia Mathematics & Science Coalition [VMSC], 2013). Employing inquiry entails teachers asking the right questions at the right time and ushering possible places to search for answers (Dira-Smolleck, 2004). Within the umbrella of SI are Scientific Reasoning (SR) and Process Skills (PS) (Pratt & Hackett, 1998, as cited in Ergül et al., 2011). Students who may be good at data analysis (SR) but poor at experimental design (PS) may generate flawed data and produce inaccurate reasoning.

Bandura (1994) characterized perceived self-efficacy as people's belief in their ability to achieve specific levels of performance. This belief then influences people's actions. This idea from Bandura was contextualized into teaching, linking teachers' self-efficacy to that of their respective students. To develop students' SR and PS in Biology, the educational system must take into consideration the teachers' self-efficacy. According to Bandura (1994), teachers who have high instructional self-efficacy speak of their capability to motivate and enhance their students' cognitive development. Conversely, those with low instructional self-efficacy tend to adopt a custodial approach to drive students to study (Bandura, 1994). Some studies that support this notion claim that teachers who have higher efficacy have less angry or negative interactions in their teaching (Ashton et al., 1982, as cited in Tschannen-Moran & Hoy, 2001; Guo et al., 2012). In other studies, teacher self-efficacy was found to positively influence student motivation and achievement (Mojavezi & Tamiz, 2012; Shahzad & Naureen, 2017). When it comes to biology instruction, Savran and Çakiroglu (2001) found out that positive efficacy beliefs were communicated by pre-service teachers in view of their ability to teach Biology.

Implementation of SI necessitates the development of SR. Scientific reasoning is a self-regulating system of inquiry that relies on empirical evidence to describe, understand, predict, and control natural phenomena (Association of American Colleges and Universities [AACU], 2010). Students are challenged to create explanations from data, compare these explanations to existing scientific knowledge, and convey these ideas when making inquiries (National Academy of Sciences, 1996; VMSC, 2013). Students' abilities to reason out scientifically in the areas of analyzing, evaluating, and creating are enhanced through this process (Yanto et al., 2019). Empowered teachers can aid students in strengthening their scientific augmentation skills (Erduran et al., 2004, as cited in Fischer et al., 2014).

Theory and practice are wedded in biology classes through inquiry-based activities. Padilla (1990, as cited in Tan, 2017a) defined PS as an array of abilities that mirrors a scientist's thinking and behavior. Students can participate in science directly through process skills when they use practical methods to solve problems (Abungu et al., 2014). Process skills have also been found to positively and significantly predict students' understanding of concepts in Biology (Tan, 2017a). Students do not start with a strong set of process skills. This is why teachers must deliberately target them in the content to improve these skills (Exploratorium, 2006).

The teachers play a role in implementing scientific inquiry and improving students' scientific reasoning and process skills. One factor that could be investigated would be the efficacy of science teachers in inquiry-based instruction. Dira-Smolleck (2004) asserted that teachers must build their self-efficacy in Scientific Inquiry as learners and as teachers. Through this, they may channel their own skills into their teaching strategies and methods to improve their students' scientific reasoning and process skills. While teachers' self-efficacy may influence performance, Bandura (1994) recognized that there is a tendency for people to miscalibrate their performance as there is a dissension and a lot of things playing in between theory and practice.

Literature about the influence of teachers' self-efficacy on their students' performance is growing, but gaps remain. Literature that would give perspective on how these variables play on a bigger scale, especially in the Philippine setting, is lacking. For this reason, this study aimed to find out the answer to the following questions:

Firstly, do components of science teachers' inquiry efficacy beliefs influence the components of students' scientific reasoning and process skills in Biology?

Secondly, is there a positive relationship between the components of scientific reasoning and the components of process skills in Biology of students exposed to teachers' inquiry efficacy beliefs?

Methods

Research Design

The study used a survey research design. The quantitative strand centered on investigating the influence of Teachers' Inquiry Efficacy Beliefs (TIEB) on students' SR and PS in Biology. It also investigated the relationship between students' scientific reasoning and process skills. To understand the practical application of scientific inquiry, select teachers were asked to provide their insights on its implementation through the information sheet given to them.

Sample

The sample was composed of 56 Grade 9 science teachers, 24 from Quezon City and 32 from Manila public high schools. One thousand nine hundred sixty-eight (1968) public school students were surveyed. These students were from each class handled by 24 teachers in the School Year 2018-2019 in Quezon City and 32 teachers in the School Year 2019-2020 in Manila. Specifically, 831 students were from Quezon City and 1,137 students were from Manila. These two cities comprised the biggest population in the National Capital Region, Philippines [*Highlights of the National Capital Region (NCR) population 2020 census of population and housing (2020 CPH)* 2021]. Aside from population size, the choice of the selected cities was of practicality and accessibility, considering factors and limitations such as proximity, funding, and logistics.

Most teachers reported to be General Science majors, which was 32.14% (n=18) of the sample. For the context of this study, Biology majors were 21.43% (n=12) of the sample. In terms of overall teaching experience (range=2-42 years), teachers who have been teaching for 6-10 years comprised the biggest population with 26.79% (n=15). While there were teachers who were new to the public school system, none of them were totally new to the teaching profession.

Instruments

Instruments used in the study have been developed by other researchers and were selected because of their reliability and could be administered to high school students regardless of students' expected scientific knowledge.

Self-Efficacy Beliefs in Regard to Teaching of Science as Inquiry (TSI)

Self-Efficacy Beliefs in Regard to Teaching of Science as Inquiry (TSI) Instrument (Dira-Smolleck, 2004) gauged TIEB. It has Cronbach Alpha values of .6579-.7582. This study used 34 items from the personal efficacy portion of TSI with 69 items since it has been found to be more effective in predicting behaviors than outcome expectancy (Schunk & Miller, 2002, as cited in Joern, 2009). These 34 questions were distributed among five sections of the essential features of classroom inquiry (EFCI). The components of TIEB are: learners are engaged in scientifically oriented questions - Question (EFCI 1), learners prioritize evidence when responding to questions - Evidence (EFCI 2), learners base their explanations on evidence - Explanation (EFCI 3), learners evaluate their explanations and consider alternative explanations, particularly those that reflect scientific understanding - Evaluation (EFCI 4), and learners communicate and justify their explanations - Communication (EFCI 5).

The original TSI instrument used a 5-point Likert scale (5 - Strongly Agree, 4 - Agree, 3 - Uncertain, 2 - Disagree, and 1 - Strongly Disagree). However, for this study, it was modified to a 4-point Likert scale (4 – Strongly Agree, 3 - Agree, 2 - Disagree, 1 - Strongly Disagree). The purpose of this modification was to remove the neutral answer and to make a definitive decision when teachers were responding to each item.

Lawson's Classroom Test of Scientific Reasoning (LCTSR)

Lawson's Classroom Test of Scientific Reasoning (LCTSR) was used to quantify students' SR. LCTSR is a 24-item multiple choice type of test that measures the ability of the students to apply scientific and mathematical reasoning. It scored .71 in its internal consistency using Cronbach's alpha (Yunting, 2017).

The evaluated reasoning patterns and the related item pairs are shown in Table 1.

Table 1

Assessed Reasoning Patterns and Item Equivalence in LCTSR

Assessed Reasoning Patterns	Paired Items Involved in LCTR
Conservation of weight	1, 2
Conservation of displaced volume	3, 4
Proportional thinking	5, 6
Advanced proportional thinking	7, 8
Identification and control of variables	9, 10
Identification and control of variables and probabilistic thinking	11, 12
Identification and control of variables and probabilistic thinking	13, 14
Probabilistic thinking	15, 16
Advanced probabilistic thinking	17, 18
Correlational thinking (includes proportions and probability)	19, 20
Hypothetico-deductive thinking	21, 22
Hypothetico-deductive reasoning	23, 24

Based on Lawson, A. (1978 and 2000). *Classroom test of scientific reasoning.* Arizona State University.

For the purpose of the study, the reasoning patterns were lumped into six components: conservation of weight and volume (SR 1), proportional thinking (SR 2), identification and control of variables (SR 3), probabilistic thinking (SR 4), correlational thinking that includes proportions and probability (SR 5), and hypothetico-deductive thinking and reasoning (SR 6). These items were not necessarily focused on Biology. It is also worth noting though that these items touch on quantitative reasoning, an essential skill in Biology, and across other science disciplines.

Science Process Skills Test (SPST)

The Science Process Skills Test (SPST) (Tan, 2017a) measured students' PS in Biology. It is composed of 35 multiple-choice items and has a high degree of internal consistency, having a Cronbach alpha value of .897 (Tan, 2017a). The theme of these items revolved around Biology. Sample items include having the students label variables and visualize or decide the best experimental set-ups. Some topics included are plants, health, and photosynthesis.

Table 2 lists the assessed process skills in Biology and the items involved.

Table 2

Assessed Process Skills in Biology and Item Equivalence in SPST

Assessed Process Skills in Biology	Items Involved
Inferring	14, 18, 24, 26, 27
Predicting	15, 22, 23, 25
Identifying and Controlling Variables	1, 2, 3, 4, 5, 6, 17, 21
Interpreting Data	7, 8, 9, 10, 11, 12, 13, 16, 19, 20, 28, 29, 30, 31, 32, 33, 34, 35

Source: Tan, R. (2017b). *Science process skills test.*

The 35 items were distributed among four process skills: inferring (PS 1), predicting (PS 2), identifying and controlling variables (PS 3), and interpreting data (PS 4).

Data Collection Procedure

There were two stages to the data collection process. The data collection for teachers was the initial phase. Schools from Quezon City and Manila were chosen from those with the biggest student populations and their disposition to participate. In Grade 9 Science, the curriculum is divided into four quarters: "Living things and their environment," "Matter," "Earth and space," and "Force, motion, and energy," respectively (DepEd, 2015). Data collection from these cities was scheduled to take place after the first grading period, the quarter when Biology was taught in Science 9.

A total of 56 teachers from different schools consented to participate. Teachers were asked to fill out the TSI questionnaire in order to collect data for the TIEB. In the same information sheet that was given to them, teachers assigned in Manila were asked about their experiences in implementing inquiry-based activities to gain deeper insights beyond quantitative data and add to the credibility and robustness of the study's outcomes. Once done, teachers were asked to seal the questionnaire in the provided envelope.

Teachers from Quezon City, however, where the study was first conducted, shared their experiences verbally. Regrettably, due to the absence of proper documentation and permission from the teachers, the discussions from them cannot be integrated into the study.

The second phase was the data collection for students. Only one Grade 9 science class assigned to a teacher responded to LCTSR and the SPST. Class selection depended on the schedule that would maximize the time and mobility of three sets of test booklets during the approved period of the survey. Each set of test booklets provides the class with both the LCTSR and the SPST. LCTSR was used to determine students' Scientific Reasoning, while SPST was used to measure Process Skills in Biology. The participating class finished answering the two tests in their 50-minute period in science. Students were not given any review material to prepare for the tests. The students surveyed totaled 1,968.

For data management, teacher responses in the teacher background survey (Joern, 2009) were encoded in plain text, while their answers in TSI were averaged per component of TIEB. Student answer sheets were checked, and a point was assigned for every item correctly answered. These individual responses were later added with other items of the same component for 1) scientific reasoning and 2) process skills in Biology. Should there be any no-answer to items, whether for the lack of time or inability to answer, they were still included to represent the characteristics of that subset of the sample. After checking, student scores per component of scientific reasoning and process skills in Biology were filed alongside their respective science teacher.

Data Analysis Procedure

Linear regression was done to determine the influence of the components of TIEB on the components of students' scores in scientific reasoning and process skills in Biology. The data that were used were scores of the components of TIEB, scientific reasoning, and process skills in Biology. The components of TIEB were set as independent variables, while the components of scientific reasoning and process skills were set as dependent variables. For the dependent variables, a one-tailed Pearson product moment correlation was used to determine if there are positive relationships between the components of scientific reasoning and the components of process skills in Biology.

To interpret the efficacy of teachers from the weighted mean, the following rating scale was followed: 1.00-1.75, Very low degree of self-efficacy, 1.76-2.50, Low degree of self-efficacy, 2.51-3.25, High degree of self-efficacy, and 3.26-4.00, Very high degree of self-efficacy (Abad & Galleto, 2020). Student scores per component of scientific reasoning and process skills in Biology were filed alongside their respective science teacher's component of TIEB.

Results

Science Teachers' Inquiry Efficacy Beliefs

Scores for items designated for each Essential Feature of Classroom Inquiry are shown in Table 3.

Table 3

Average Self-efficacy on Essential Features of Classroom Inquiry (EFCI) and TIEB

Five Essential Features of Classroom Inquiry	Average	Interpretation
EFCI 1. Learners are engaged in scientifically oriented questions. (Question)	3.31	Very high degree
EFCI 2. Learners prioritize evidence when responding to questions. (Evidence)	3.32	Very high degree
EFCI 3. Learners base their explanations from evidence. (Explanation)	3.33	Very high degree
EFCI 4. Learners evaluate their explanations and consider alternative explanations, particularly those that reflect scientific understanding. (Evaluation)	3.36	Very high degree
EFCI 5. Learners communicate and justify their explanations. (Communication)	3.39	Very high degree
Overall TIEB Average	3.34	Very high degree

Legend: 1.00-1.75 – Very low degree of self-efficacy   2.51-3.25 – High degree of self-efficacy
1.76-2.50 – Low degree of self-efficacy   3.26-4.00 – Very high degree of self-efficacy

All EFCIs' averages fell under the range that characterizes very high degrees of agreement with statements about their ability to teach inquiry-based science. The overall average TIEB of the sample was found to be 3.34 (N=56). This can be interpreted that teachers strongly believe in their ability to teach inquiry-based science.

Influence of the Components of Science Teachers' Inquiry Efficacy Beliefs on the Components of Students' Scientific Reasoning

Table 4 exhibits the obtained TIEB and students' average scores in scientific reasoning.

Table 4

Overall Teachers' Inquiry Efficacy Beliefs and Students' Scientific Reasoning Scores

Schools' Location	Average TIEB	Average SR
Quezon City	3.44 (SD = 0.32)	22.39% (SD = 3.87)
Manila	3.26 (SD = 0.31)	21.74% (SD = 3.05)
Overall	3.34 (SD = 0.32)	22.02% (SD = 3.41)

In the combined samples from Quezon City and Manila, the average TIEB score was 3.34 (N=56). In reference to the rating scale, this score indicates that teachers have a very high degree of self-efficacy in teaching inquiry-based science. Students, on average, scored 5.28 out of 24 items (22.02%) on scientific reasoning.

Linear regressions were done to determine if the components of science teachers' efficacy beliefs influence the components of students' scientific reasoning. Among the results of the regression models, only the component Teacher Inquiry Efficacy Belief that deals with Explanation from Evidence predicted the component Student Scientific Reasoning on Identification and Control of Variables (Table 5).

Table 5

Regression Analysis Summary for Teacher Inquiry Efficacy Belief on Explanation from Evidence Predicting Student Scientific Reasoning on Identification and Control of Variables

Variable	B	SE	ß	T	p
Constant	.570	.227	2.516	2.516	.012
Teacher Inquiry Efficacy Belief on Explanation from Evidence (EFCI3)	.190	.068	.063	2.811	.005

Results: $F(1,1966)=7.902$, $p=.005$, $R^2_{adjusted}=.004$

It has been found that there is a statistically significant association between the independent variable EFCI 3 and the dependent variable SR 3, as indicated by the *F*(1,1966) value of 7.902 and a p-value of .005. Specifically, the Teacher's Inquiry Efficacy Belief on Explanation from Evidence significantly predicts Student Scientific Reasoning on Identification and Control of Variables, *B*=.190, *t*=2.811, p=.005.

Influence of the Components of Science Teachers' Inquiry Efficacy Beliefs on the Components of Students' Process Skills in Biology

Table 6 shows the obtained TIEB and students' average scores in the process skills test in Biology.

Table 6

Overall Teachers' Inquiry Efficacy Beliefs and Process Skills Scores

Schools' Location	Average TIEB	Average PS
Quezon City	3.44 (SD = 0.32)	33.74% (SD = 8.82)
Manila	3.26 (SD = 0.31)	30.28% (SD = 6.6)
Overall	3.34 (SD = 0.32)	31.76% (SD = 7.75)

The overall average score of students' process skills in percent is 31.76% (N=1968). Students scored, on average, 11 out of 35 items (31.76%) in the SPST.

To find out if the components of science teachers' inquiry efficacy beliefs influence the components of students' process skills in Biology, linear regressions were also done. In this part, the components of science teachers' inquiry efficacy beliefs were the independent variables, while the components of students' process skills in Biology were the dependent variables. No significant influences were found at the .05 level.

Relationship between the Components of Scientific Reasoning and Process Skills in Biology

Table 7 details the Pearson product-moment correlation between students' scientific reasoning and process skills in Biology.

Table 7

Pearson product moment correlation between Students' Scientific Reasoning and Process Skills in Biology (N=1968)

		PS
SR	Pearson Correlation	.21**
	Sig. (1-tailed)	.000
	N	1968

**. Correlation is significant at the 0.01 level (1-tailed)
Legend: 0-0.19 – very weak; 0.2-0.39 – weak; 0.40-0.59 – moderate; 0.6-0.79 – strong; 0.8-1 – very strong

The relationship between students' scientific reasoning and process skills in Biology was assessed. A one-tailed Pearson product-moment correlation showed that there was a weak positive correlation between scientific reasoning and process skills in Biology, r=.21, p=.000, N=1968.

The strength of association was interpreted using the scale: 0-0.19, Very Weak, 0.2-0.39, Weak, 0.40-0.59, Moderate, 0.6-0.79, Strong, 0.8-1, Very strong (Campbell, 2021).

Furthermore, to assess the relationship between the components of students' scientific reasoning and process skills in Biology exposed to teachers' inquiry efficacy beliefs, one-tailed Pearson product-moment correlations were computed. Table 8 presents these correlations.

Table 8

Pearson Correlation Analyses of Components of Scientific Reasoning and Components of Process Skills in Biology (N=1968)

	PS 1: Inferring	PS 2: Predicting	PS 3: Identifying and controlling variables	PS 4: Interpreting data
SR 1: Conservation of weight and volume	.12**	.15**	.11**	.13**
SR 2: Proportional thinking	.05*	.02	.02	.01
SR 3: Identification and control of variables	.09**	.09**	.06**	.10**
SR 4: Probabilistic thinking	.09**	.05*	.13**	.11**
SR 5: Correlational thinking	.03	.04	.00	.04*
SR 6: Hypothetico-deductive thinking and reasoning	.00	.01	-.01	.03

**. Correlation at .01 level (1-tailed).
*. Correlation at .05 level (1-tailed).

The correlations of conservation of weight and volume (SR 1), correlations for identification and control of variables (SR 3), and probabilistic thinking (SR 4) with all the four components of process skills in Biology were statistically significant, though very weak, $r \geq .09$, $p < .05$, $N=1968$. However, correlations of proportional thinking (SR 2) with the components of process skills in Biology were not significant, except for inferring (PS 1), $r=.05$, $p=.015$, $N=1968$. Pearson correlation tests showed no statistically significant relationship for correlational thinking (SR 5) with the components of process skills in Biology except for interpreting data (PS 4), $r=.04$, $p=.026$, $N=1968$. Additionally, Pearson correlation tests showed no statistically significant relationships between hypothetico-deductive thinking and reasoning (SR 6) with the components of process skills in Biology. Overall, the results suggest that 14 out of 24 correlations between the components of scientific reasoning and process skills in Biology were statistically significant.

Discussion

Influence of the Components of Science Teachers' Inquiry Efficacy Beliefs on the Components of Students' Scientific Reasoning

Linear regressions were done to determine the influence of the EFCIs on components of students' scientific reasoning. Among the results of the regression models, it was only significant for a component of Teacher Inquiry Efficacy Belief that deals with Explanation from Evidence as a predictor of a component of Student Scientific Reasoning on Identification and Control of Variables, $F(1,1966)=7.902$, $p=.005$ (see Table 5). However, the $R^2_{adjusted}$ value of 0.004 suggests that EFCI 3 explains a very small proportion of the variance in SR 3. This suggests that while acknowledging the statistically significant result, the practical significance or effect size of this relationship is minimal. This could also indicate that for a sample this big, EFCI 3 and PS 3 may be influenced by other unaccounted moderating variables.

When examining the impact of EFCI 3 on the components of scientific reasoning, no adequate evidence of influence was found, except for the identification and control of variables – one of the early steps in a scientific inquiry. This suggests that students could still be in the early beginnings of developing their scientific reasoning abilities through teachers' inquiry efficacy beliefs. To strengthen and confirm this finding, additional tests with more items pertaining to identifying and controlling variables under scientific reasoning must be done.

Students, too, were found to have low scientific reasoning abilities (see Table 4). Supporting data from Table 3 point out that teachers believed that their students prioritize evidence when responding to questions. This high efficacy, however, did not translate well into their students' scientific reasoning abilities, which were rather low.

There may be other reasons that could explain the low Scientific Reasoning scores. The first probable explanation is a lack of scientific knowledge. Scientific reasoning reinforces the formation and modification of concepts and theories about the world (Bao et al., 2009). A person may not be able to reinforce or modify concepts without a solid foundation in scientific concepts. When a person starts to reason not grounded on evidence, facts, and logic, strong cognitive bias may surface, and his/her argument may be dependent on emotion that clouds sound judgment.

The second probable cause for low scientific reasoning scores is the lack of proper student mentoring. Scientific knowledge can positively predict scientific reasoning skills, but an overemphasis on factual recall may also hinder students from having a deep understanding of scientific reasoning (Bao et al., 2009). Most of the teachers sampled were General Science majors (32.14%). The rest of the teachers differ in subject specialization. Mastery of subject matter influences the effectiveness of the implementation of the curriculum (Duze, 2012, as cited in Resurreccion & Adanza, 2015).

It is not surprising that most teachers surveyed were General Science majors. The Philippines follows a spiral curriculum, wherein the different science disciplines are taught per grade level. While General Science teachers are well-rounded and can teach one science discipline after another, some topics may require mastery. Literature contends that when teachers teach subjects beyond their subject mastery, lessons may lack in-depth discussions (Igcasama, 2021; Resurreccion & Adanza, 2015). It is difficult to teach intentionally, emphasize key understanding, and point out any misconception that may arise from the discussion when there is insufficient knowledge of the subject at hand.

Poor scientific reasoning skills lead to difficulty solving problems, a shallow understanding of theoretical concepts, and a refusal to reject prior belief structures (Lawson, 2004). The low scientific reasoning scores result is not an isolated case (Hoffenberg, 2013), but it does not mean that the situation cannot be improved. Students would need scientific reasoning abilities to appropriately participate in the discussion of biological issues such as mitigation of climate change, accessing safe food and clean water, and managing epidemics and pandemics.

Influence of the Components of Science Teachers' Inquiry Efficacy Beliefs on the Components of Students' Process Skills in Biology

Linear regressions were performed to determine the influence of the components of TIEB on components of students' process skills in Biology. No significant influences were found at .05 level. Interestingly, EFCI 3 has no statistically significant influence on students' skills in controlling variables (PS 3), contrary to its significant influence on SR 3 (see Table 5). While there may be a lot of interlacing similarities between SR 3 and PS 3, SR 3 includes items that cover probabilistic thinking, which may not be the focus of the items for PS 3. Specifically, an item under PS3 may pose a problem and ask to identify the appropriate experimental setup (see Tan, 2017b), while an SR 3 item may seek to explain the reasoning behind the setup and how it would unfold (see Lawson, 2000). Since the students were asked to justify their answers, it may be argued that Explanation (EFCI 3) is more closely related to SR 3.

Data from Table 6 revealed that students have poor process skills in Biology. When crossed with Table 3, it was shown that teachers believe that their students are engaged in scientifically oriented questions, and they prioritize evidence when responding to questions. Teachers believe that they can provide meaningful experiences to students, allow students to devise their own problems to investigate, and encourage students to gather the appropriate data necessary for answering their questions. The reported high self-efficacy of teachers (TIEB of 3.34) did not influence the students as desired since results show low performance in process skills in Biology.

While there were no significant influences found, this does not mean that teachers' self-efficacy in inquiry-based learning has nothing to do with effective instruction of science process skills.

There are benefits of high self-efficacy. Bandura (1994) maintained that overestimation of one's ability is beneficial because people with high self-efficacy have stronger beliefs that situations that may arise can be managed. It also suggests that the teachers are going beyond ordinary means to boost their performance, and the optimistic sense of personal efficacy entails accomplishments and positive well-being (Bandura, 1994). Savas' (2014) study showed that teacher self-efficacy was negatively correlated with burnout. It has been found that higher teaching self-efficacy is linked to lower teaching anxiety in Biology (Chen Musgrove & Schussler, 2022). This is noteworthy because in the spiral curriculum, teachers who are non-Biology majors may be asked to teach biology-related topics. Perhaps this high degree of self-confidence may have helped the teachers cope with the challenges of running the 21st-century science classes. Data from the survey say that 12 out of 56 teachers (21.43%) were Biology majors. Grade 9 biology topics may include the respiratory system, circulatory system, non-Mendelian genetics, species extinction, photosynthesis, and cellular respiration (DepEd, 2015). Each of these topics has nuances and common misconceptions that may be easier to address if someone is trained in Biology.

Low process skills scores indicate that students cannot perform well in scientific processes such as observing, inferring, measuring, communicating, classifying, and predicting. A possible explanation for the low scores in process skills in Biology is subject mastery mismatch. There is also a lack of training to improve teachers' science process skills. Research has asserted that to properly equip students with science process skills, teachers must possess those very same skills (Mutisya et al., 2014). Only 8 out of 56 teachers (14.29%) claimed to have research experience in this study. This is a problem because teachers rely on teaching methods that are familiar to them (Eick & Reed, 2002, as cited in Steward, 2007). Without a research background to be grounded in, teachers may find discomfort in implementing a research-oriented method of teaching. Teachers who lack sufficient scientific background or subject mastery tend to control students' activities within their area of knowledge. This may provide an insight why some teachers opt not to use inquiry in their class and rather resort to methods that are more familiar to them.

Another possible explanation for the low process skills scores is the undue implementation of "cookbook labs." "Cookbook labs" are typically prescriptive laboratory activities where there are step-by-step procedures followed by students. Laboratory manuals have been criticized for not emulating how scientists carry out scientific investigations because they leave fewer opportunities for trials, criticism, revisions, and repetitions (AAAS, 1993). Cookbook labs are not without merit. They may serve as bridges that familiarize students with the scientific phenomenon or concept in focus and develop important science skills (AAAS, 1993). The problem emerges when there is no follow-up structured, guided, or open type of inquiry. Teacher-directed discussions and scientific investigations are not to be downplayed. A study by Gee and Wong (2012) uncovered that students who have science lessons that emphasize models or applications have higher achievement in science than those who have independent investigations.

This underscores the importance of scaffolded discussions and investigations. Practical and applicable knowledge of biology concepts may help students in making informed decisions about their health, the environment, and society at large.

Triadic Reciprocal Determination

Triadic reciprocal determination may provide an insight into the disparity of TIEB and students' scientific reasoning, and that of TIEB and students' process skills in Biology. This theory of Bandura (1989) favors the idea that behavior, personal factors, and environment interact and influence each other in two bidirectionally. It was also important to consider what happens during the transmission process. In the same information sheet given to them, teachers assigned in Manila were asked about their struggles in implementing scientific inquiry. Similar responses were grouped together, and major factors or barriers that could affect effective transmission were found to be time constraints, large class sizes, lack of resources, and lack of student comprehension and participation. In this context, a teacher who may have the necessary skills of running Scientific Inquiry may be affected negatively in handling the class by limited resources.

Many teachers remarked about the lack of time for science classes. All public schools that were surveyed have 50 minutes of science per day, five days a week. Included in the 50-minute window were daily routines such as prayer, greetings, checking of attendance, and moving in between periods. They have a rigid time frame that prompted teachers to abandon time-consuming inquiry-based activities. This makes teachers resort to strategies that would allow them to manage time easily such as lecture-based discussion, thinking of inquiry-based instruction as extra-work.

Continuing with the large class sizes, the full capacity of the public high schools sampled could be as large as 50; some schools claim to have more. Teachers also cited the lack of facilities, resources, laboratory apparatus, and materials for instruction.

As per the student factor, teachers commented on the quality of students' participation. Teachers saw that students struggled with analysis, comprehension, procedural understanding, and appropriate responses. While lack of enthusiasm was attributed to students' incapability or appreciation of scientific inquiry, the idea seemed counterintuitive to scientific inquiry's goal, which was to improve students' knowledge and viewpoint of science (National Research Council [NRC], 2000). Rather than the students being uninterested in scientific inquiry activities, the lack of students' interest could indicate that scientific inquiry was not implemented to a sufficient degree, not enough to impact areas like scientific reasoning and process skills. Some teachers also think that inquiry is not for low-performing students and that not all students can respond to challenging scientific questions. While teachers' frustration and woes with some of the students may be understandable, and while there were several unidentified factors that were at play when in class, these views should be recognized as problematic. This is because of the assumption that a stereotyped class or student would not perform well in inquiry-based learning, instead of equipping them skills to be successful at it. Teachers should also be careful about what they deem their students can do. Previous literature has argued that teachers' biases could influence students' performance (see Alan et al., 2018, for research on gender stereotypes and Bonefeld & Dickhäuser, 2018 for insights on student migrant background).

Fairly speaking, the task of equipping students with inquiry skills is not meant to be solely carried by the teachers and needs further support from other stakeholders. Several research conducted in idealized or controlled settings have affirmed the benefits of inquiry-based teaching on student learning (e.g., Bridges, 2017; Li et al., 2018; Radulovic et al., 2016). This suggests that when teachers and students are provided the support and resources they need, the mediating variables would not act as barriers but as assistance that would help students achieve things through inquiry (see also Akomolafe & Adesua, 2016).

Relationship Between the Components of Scientific Reasoning and Process Skills in Biology

The relationship between students' scientific reasoning and process skills in Biology was assessed using a one-tailed Pearson product-moment correlation. The analysis showed a weak positive correlation between scientific reasoning and process skills in Biology, r=.21, p=.00, N=1968.

The same process was also done to assess the relationship between the components of students' scientific reasoning and the components of process skills in Biology exposed to teachers' inquiry efficacy beliefs. One-tailed Pearson product-moment correlations revealed that 14 out of 24 correlations between the components of scientific reasoning and the process skills used in Biology were statistically significant (see Table 8).

Correlations found were of weight and volume (SR 1) and all components of PS in Biology. Similar associations were found between the identification and control of variables (SR 3) and all components of PS in Biology, as well as probabilistic thinking and all the components of PS in Biology. Furthermore, a correlation was found between proportional thinking (SR 2) and inferring (PS 1), and between correlational thinking (SR 5) and interpreting data (PS 4).

All in all, the positive correlation between scientific reasoning and process skills in Biology can help predict the score of the other. From here, scientific reasoning and process skills are directly proportional. Put in context, a student who has high scientific reasoning ability tends to have good process skills in biology, but in a similar manner when a student has low scientific reasoning ability, he/she also tends to perform poorly on process skills in Biology.

Conclusion

A total of 56 Grade 9 science teachers and 1968 students from Quezon City and Manila were surveyed to examine the influence of science TIEB on students' scientific reasoning, and process skills in Biology.

The teachers' belief that their students base their explanation on evidence (EFCI 3) has been found to influence students' skills in the identification and control of variables (SR 3). A linear relationship between the rest of the components of TIEB and students' scientific reasoning, and between TIEB and students' process skills in biology cannot be established. The teachers have been found to have high self-efficacy, and it may be a coping mechanism in response to the challenges in teaching. Moreover, several factors have been identified that hinder teachers from implementing scientific inquiry successfully. These factors were time constraints, large class sizes, lack of materials, and students' low level of comprehension and participation.

Positive correlations between 14 out of 24 components of scientific reasoning and process skills in Biology were found to be statistically significant, although notably very weak. These correlations were between: weight and volume (SR 1) and all components of PS in Biology, identification and control of variables (SR 3) and all components of PS in Biology, probabilistic thinking and all the components of process skills in Biology; correlation of proportional thinking (SR 2) and inferring (PS 1); and correlation of correlational thinking (SR 5) and interpreting data (PS 4). As a whole, students' scientific reasoning and process skills in Biology have been found to have a positive correlation. In other words, as scientific reasoning increases, process skills tend to increase likewise.

The results, together with the barriers that teachers identified in scientific inquiry, imply that their current implementation, which aims to augment the two variables, is not sufficient to influence students' scientific reasoning and process skills in Biology.

As a recommendation, it is worth emphasizing that while Explanation (EFCI 3) can influence identification and control of variables (SR 3), the rest of the linear regressions performed found no significant influence of the components of science teachers' inquiry efficacy beliefs on the other components of students' scientific reasoning and the components of process skills in Biology. To be more conclusive about this finding, a separate study that has more items that deliberately target the mentioned variables may be done.

A qualitative study may be done to see the interaction of science teachers' inquiry efficacy beliefs and students' scientific reasoning and process skills in Biology in a classroom setting. Scientific reasoning and process skills in Biology have been found to have a positive correlation; for this reason, future researchers may explore whether teachers' scientific reasoning affects students' process skills and vice-versa.

Teachers and pre-service teachers are advised to be actively involved in scientific research. Reducing the teaching load of practicing teachers when they handle scientific research may allow them to have more time for student consultation. It is sensible to address the gap between what the teachers are trained to be and to what the current curriculum necessitates, which is inquiry-based learning.

The timetable of the learning competencies should be less rigid and should offer more flexibility. This approach minimizes the tendency to abandon time-consuming inquiry-based activities in favor of lecture-based discussions (see Kang & Keinonen, 2016). Additionally, limiting class sizes to 32 students is also optimal, as it allows for the necessary support of individualized needs (Dixon, 2011, as cited in Kang & Keinonen, 2016). In managing big class sizes with rigid timelines, guiding and mentoring students may be difficult to implement. Consequently, teachers may find themselves addressing students' issues generally rather than attending to individual student needs.

Lastly, through the interviews with some of the teachers, there seems to be a recurring theme that touches on the perception of teachers that not all students are capable of scientific inquiry. Teachers should see students as works in progress rather than individuals who already have a fixed set of skills and abilities. Regardless of where students come from, teachers should offer support and equip them with inquiry skills. Of course, adequate support and resources for teachers must be given. As such, it may interest future researchers to see if teachers' expectations of student abilities mediate teachers' scientific inquiry instruction in the Philippines.

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Authors' Bionotes

Paula Esperanza Y. Ortha is a faculty member in the Department of Biology, College of Science, Polytechnic University of the Philippines (PUP). This paper is based on Ms. Ortha's master's thesis from the University of the Philippines College of Education. Her research interest is Biology Education.

Rosanelia T. Yangco is a retired professor of the University of the Philippines College of Education. She is the thesis adviser of Ms. Ortha. Her research interests are in Biology Education and Environmental Education.

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