ANALYSIS OF THE LEVEL OF INQUIRY IN THE UNDERGRADUATE SCIENCE EDUCATION LABORATORY

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ABSTRACT

A common goal for science educators is to engage students in inquiry. Policy makers present inquiry as a continuum and several researchers extrapolate that this continuum is represented by a figure that moves from more to less guidance. Thus inquiry activities are labeled from more structure (low - level inquiry) to less structure (high - level inquiry).

This study characterized the level of inquiry in the undergraduate science education laboratory in a State University in the Cordillera Administrative Region. The implication of the result to the preparation of teachers in the K – 12 levels was also discussed.

Ten laboratory manuals in three fields of science were analyzed. All of these manuals are utilized by science education majors. From these ten laboratory manuals, 147 exercises or activities were evaluated. Each of the laboratory activities was rated from level 1 – confirmatory, level 2 – structured inquiry, level 3 – guided inquiry, level 4 – open inquiry, and level 5 – authentic inquiry. The ratings made were compared with those of two other evaluators and the inter-rater reliability index was determined.

Results showed that majority of the exercises are confirmatory in nature. Very few (less than 10%) of the exercises were higher than the guided inquiry level. There were limited activities involving open inquiry and no exercise involved authentic inquiry.

Results indicate that there is a need for professors handling science education majors to focus on less-structured forms of inquiry in their laboratory activities. It is a part of the instructor's responsibility to plant the seeds of real inquiry to the minds of future science teachers in order to better prepare them to handle science in the K – 12 levels.

KEYWORDS:
Inquiry, Levels of Inquiry, Science education majors, K – 12 science education.

INTRODUCTION

A common goal for science educators is to engage students in inquiry. The incorporation inquiry-based learning facilitates the learning of difficult concepts. If science classes are viewed as a place where the students can use their fertile minds to solve problems, gather data, explore new avenues, or create different solutions, educators will find that these students respond favorably and learn science meaningfully. In the process of being involved in their own learning, students will develop certain desirable knowledge, skills, and attitudes that will stay with them throughout their lives. After all, scientific literacy is not developed merely by being able to read science materials with understanding, but by developing afull appreciation of where scientific information comes from, the differences between science and technology, and how each of these affect society (Trowbridge, *et al*., 2000).

In response to the call for scientific literacy, and realizing that this cannot be accomplished by using the traditional method of teaching, science teachers have used methods of teaching using investigative, inquiry approaches to learning the content and processes of science. These efforts have been met with varying success; the challenges of inquiry teaching are still very evident, and the shift from the traditional expository method has been very slow (Lunsford & Melear, 2004; Shiland, 1999).

Scientific inquiry has been defined as "a systematic investigative performance ability which incorporates unrestrained inductive thinking capabilities after a person has acquired a broad and critical knowledge of particular subject matter through formal learning processes." (Kyle, 1980). The goal of inquiry-based laboratory experience is not only to provide hands-on application of materials, but also a minds-on activity that includes higher-level thinking processes. (Walker *et al*., 2008; Lumpe & Oliver, 1991). Science education reform involves bridging the gap between minds-on and hands-on activity and places the responsibility for learning on the student, not the instructor.

It is advocated by the US National Science Education Standards (NRC, 2000) that scientific inquiry should occur as a continuum. Brown *et al*. (2006) propose that this continuum can be represented by a figure that moves left to right from more to less guidance. There arevarieddefinitions for inquiry, and multiple modifiers for inquiry are quite common, including traditional inquiry, guided inquiry, structured inquiry, open inquiry, directed inquiry, inquiry learning and teaching, authentic and scientific inquiry, and partial and full inquiry (Walker *et al*., 2008; Abraham, 2005). Unfortunately, the meanings of the above terms are wide ranging, and literature reveals that the meaning of one term varies by author and journal of publication. This is not surprising because the word inquiry itself differs in usage between secondary school practitioners and instructors in the undergraduate levels. Nevertheless, it is important to point out that the inquiry activities requiring lesser guidance from the teacher are better than those requiring more guidance. If alesser amount of guidance is provided by the teacher, then, the inquiry becomes more authentic. Such is the goal of inquiry teaching, to make learners become more independent in performing the processes of science (Martin, 2012).

The curriculum framework for Philippine science education in the K-12 classroom echoes the same goal as the National Science Education Standards. In the curriculum framework for science, the goal of science education is explicitly described, as follows:

> Science education aims to develop scientific literacy among learners that will prepare them to be informed and participative citizens who are able to make judgments and decisions regarding applications of scientific knowledge that may have social, health, or environmental impacts… The acquisition of this aim is facilitated using the following approaches: multi/interdisciplinary approach, science-technology-society approach, contextual learning, problem/issue-based learning, and inquiry-based approach (Department of Education, Philippines, 2012).

These curriculum mandates for science education are supported by curriculum experts in both fields. Ogena (2011), for instance, emphasized that among other things, science and math education in the K-12 program must focus on hands-on science activities, emphasize on student research, and give attention to higher-order-thinking skills.

With these current reforms in science education, teachers must begin adopting teaching and assessment strategies that develop scientific literacy among their learners. While in-service teachers of science and math may be trained using inquiry-based learning (IBL) approaches, trainings must begin as early as during teacher-preparation stages. Pre-service science teachers must already be exposed to such pedagogical approaches. In fact, in the Standards for Professional Development for Teachers of Science, prospective science teachers are required to learn essential science content through the perspectives and methods of inquiry (NRC, 1996). Specifically, pre-service science teachers must be trained in investigating phenomena that can be studied scientifically, interpreting results, and making sense of findings consistent with currently accepted scientific understanding.

Also, it has become a practice for science teachers in the Philippines to guide their students as these students conduct science projects and investigations. It is therefore an advantage for science education graduate who has been exposed to the science process skills in his/her teacher-preparation course. Such science process skills could possibly be acquired through experiences with inquiry-based learning approaches.

The responsibility of sowing the seeds of inquiry-based learning lies more on science education professors, not on teacher-education professors. The predominant *de facto* pedagogical influence on K – 12 science teaching comes from undergraduate science professors, not teacher education professors (Pushkin, 2001, in Buck *et al*., 2008).

However, despite the emphasis on investigative and inquiry learning, and on the pedagogical role of science professors to the future K – 12 science teachers, most lower-level college science laboratory courses are still based on cookbook exercises. To the very least, many of these activities focus on demonstration. Students often go through a set of procedures within a set period of time with little or no critical thinking involved. (Glasson & McKenze, 1997). Such practice does not accrue to the supposed responsibility of science professors to infuse inquiry learning in their science instruction, for science education majors to be accustomed to, and for them to adopt in their future teaching.

In order to determine the extent to which science professors use the inquiry activities, they can be asked directly asked, or the students enrolled in their classes may be interviewed. But one objective method is to analyze the manuals used by the professors in these laboratories (Buck, *et al*., 2008). The latter procedure was chosen for this study.

In this study, the inquiry activities were classified into levels based on the amount of instructor guidance and student independence in performing the exercises. Also, it is based on the degree of structure and whether or not problems, procedures, and results are provided beforehand. The level of inquiry is not based on the complexity of the activities provided in the manual.

One of the latest rubrics used to evaluate the level of inquiry in the undergraduate laboratory was developed by Buck, Bretz, and Towns (2008). In contrast to the three characteristic - rubric developed by Herron (1971), there were six characteristics identified in this model. These characteristics are problem or question, which refers to the topic of the investigation; and "theory/background", which refers to all prior knowledge necessary to the investigation. The "procedure/design" characteristic of the rubric refers to the experimental procedures students execute, while the "results analysis" characteristic specifies how data are interpreted and analyzed. "Results communication" characterizes the manner by which data and experimental results are presented, and "conclusions" addresses whether the manual provides a summary or list of observations and results that should have been obtained in the laboratory. The authors then used the word "level" to denote the extent to which a laboratory investigation provides guidance in terms of the six characteristics. Each level denotes a specific form of inquiry that can be described as follows: Level 1 (Confirmation) – This includes activities where students simply observe or experience an unfamiliar phenomenon, or learn a particular laboratory technique (Buck *et al*., 2008). The succeeding definitions for the levels of inquiry are adopted from Banchi and Bell (2008). Confirmationinquiry is useful when a teacher's goal is to reinforce a previously introduced idea; to introduce students to the experience of conducting investigations; or to have students practice a specific inquiry skill, such as collecting and recording data. For example, you may want students to confirm that the less air resistance an object has the quicker it will fall. Students can create paper helicopters with wings of different lengths to confirm this idea. They follow the directions for doing the experiment, record their data, and analyze their results.

In level 2 (Structured Inquiry), the students can discover relationships or reach conclusions that are not already known from the manual. Students generate an explanation on the data they have collected, which must be supported bythe evidence. Using the same paper airplane example, studentswould not be told the relationship they were investigating ahead of time. They would need to use the data collected showing that airplanes with longerwings took longer to fall to understand that the longer wings created greater air resistance and slowed down the airplanes. One must note that while confirmation and structured inquiry are considered lower-level inquiries, these kinds of inquiries are important because they enable students to gradually develop their abilities to conduct amoreopen-endedinquiry.

The students decide on what tools or procedures are used to analyze results, how to present results, and what conclusions to draw in Level 3 (Guided Inquiry). The use of this level becomes more meaningful when students are given the opportunities to learn and practice experimenting and recording data in different ways. The role of the teacher is still an active one, such as providing feedbacks as to the correctness of the plans made by the students.

Level 4 or Open Inquiries give students greater freedom to choose materials and procedures, data analysis procedures, results communication, and conclusions for the experiment. It should be clear, though that it is only appropriate to have students conductingopen inquiries when they have demonstrated that they can successfully design and carry out investigations when provided with the question. This includes being able to record and analyze data, as well as draw conclusions from the evidence they have collected.

Finally, Level 5 or Authentic Inquiry is areal form of inquiry where students are not provided any of the six characteristics. In this highest level of inquiry requires the most scientific reasoning and greatest cognitive demands from the students. The learners have the purest opportunities to act like scientists, as they derive questions, design and carry out investigations, and communicating their results.

As science teachers, nothing is more desirable that to give students the opportunity to practice in the higher levels of inquiry. But this would only produce good results if these learners were exposed to inquiry activities that gradually moved, from Level 1 to the next higher levels.

This study attemptedto characterize the level of inquiry in the science laboratory manuals used at the undergraduate level, particularly those that are used by science education majors. Specifically, it (1) determined the level of inquiry of each of the activities contained in the science laboratory manuals used by science education majors; (2) compared the levels of inquiry in the Biology, Chemistry, and Physics laboratory manuals; and (3) discussed the implications of the result to K – 12 science education.

MATERIALS AND METHODS

Research Design

The study used the descriptive research design with document (laboratory manual) analysis as the main data-gathering procedure. Random interviews with science education majors were also conducted to verify and clarify some procedures in the manual, and validate the ratings given to each laboratory activity or exercise.

The Laboratory Manuals

The laboratory manuals analyzed in this study were those utilized by science education majors. Most of these manuals are also used by students in the other colleges (Human Anatomy, General Ecology, General Microbiology, General Chemistry, Organic Chemistry, Biochemistry, and General Physics). This study analyzed four laboratory manuals in biology and three manuals each in chemistry and physics. No laboratory manual in the Earth Sciences was analyzed. One hundred forty-seven exercises were analyzed in the study.

Determining the Level of Inquiry in the Exercises/Activities/Experiments

The level of inquiry in each of the exercises/activities/exercises in the manuals was evaluated using the rubrics adopted with modifications to Buck *et al*. (2008). The rubric used in this study made explicit the level of student independence facilitated by given experiment. In all cases, the level of evaluation is the level of student independence associated with each characteristic, not the complexity of the task or other criteria.

The six characteristics used to categorize the level of inquiry were those presented in the left column in Table 1.

Table 1. Rubric used to characterize levels of inquiry in the undergraduate science laboratory manuals (modified from Buck *et al*., 2008)

Characteristics	Confirmation (Level 1)	Structured Inquiry (level 2)	Guided Inquiry (Level 3)	Open Inquiry (level 4)	Authentic inquiry (Level 5)
Problem/Question/Objective	Provided	Provided	Provided	Provided	Not provided
Theory/Background/	Provided	Provided	Provided	Provided	Not provided
Material and Procedures	Provided	Provided	Provided	Not provided	Not provided
Results analysis	Provided	Provided	Not provided	Not provided	Not provided
Results communication	Provided	Not provided	Not provided	Not provided	Not provided
Conclusions	Provided	Not provided	Not provided	Not provided	Not provided

A new level, Level 0 (Worksheets) was added in the analysis since some laboratory manuals incorporated worksheets in the manual. This is surprising, as worksheets are usually placed in separate curriculum materials, such as reinforcement and study guides.

To verify and confirm the manner by which the laboratory activities were implemented in their classes, student volunteers were invited for an interview. This was done, especially in procedures which are vague and/or incomplete.

Three experts evaluated each of the exercises in the laboratory manuals in the three science disciplines, using the rubrics identified in Table 1. One evaluator, the author of this paper, is a Biology major who has been teaching courses in science education and is involved in studies in inquiry teaching and learning in Science. The two other evaluators were Chemistry and Physics majors who also handle education subjects and field study courses in education, respectively. The physics major holds a Ph.D. in Education. The researcher met with the other evaluators to discuss their ratings. Some of the ratings were modified based on the deliberations with the other evaluators.

The inter-rater reliability of the three evaluators was determined using the procedures set by Web Center for Social Research Methods (WCSRM, 2006) and Gutierrez (2008). At least three recorders are involved in observations, which are done separately. The formula for reliability (r) is given as follows:

$$r = \frac{\text{number of agreements}}{\text{total number of dimensions observed}}$$

Source: WCSRM (2006), and Gutierrez (2008)

In cases when all three evaluators do not agree, the two-out-of-three rule was followed to determine the rating of each exercise. So far, there was never an instance where all three evaluators differ in their rating of a particular exercise.

The inter-rater reliability of the three judges is computed as r = 0.899, where the evaluators agreed in 133 out of 148 exercises. Such value falls within the high to very high, indicating that the ratings are dependable and reliable (Gutierrez, 2008).

Treatment of Data

The data collected were presented in a two-way table. The tables indicate how many exercises per laboratory manual fall under each of the levels of inquiry. The overall openness or the amount of freedom provided by the laboratory manual is determined using weighted mean.

Locale of the Study

The study was conducted at a State University in the Cordillera Administrative Region of the Philippines. Although the University's main thrust is agriculture education, the College of Teacher Education is the biggest in terms of student enrolment. The College offers degrees in Secondary and Elementary Education, including Library and Information Science at the undergraduate level. Science education as a major is split into Biological Science and Physical sciences, pursuant to an existing memorandum order. Science courses are handled by professors in the service college of the University, the College of Arts and Sciences.

RESULTS AND DISCUSSION

The results on the level of inquiry in the laboratory manuals used by science education majors are presented separately in tables, according to discipline. The presentation begins with the laboratory manuals in Biology, then Chemistry, then Physics. The level of inquiry in the Biology laboratory manuals appear to be the highest, followed by the manuals in Physics, then by the Chemistry manuals.

Levels of Inquiry in the Undergraduate
Biology Laboratory

Table 2 shows the titles of the laboratory manuals analyzed and evaluated in this study, the number of experiments contained in each manual, the number of activities that fall under each level, and the weighted mean of each laboratory manual.

Table 2. Levels of Inquiry in the Laboratory Manuals in Biology

Title of Laboratory Manual	Level						n	WM
	0	1	2	3	4	5		
Laboratory Manual in Human Anatomy and Physiology	8	13	2	1	0	0	24	0.83
Laboratory Manual in Principles of Genetics	4	6	2	0	0	0	12	0.83
Laboratory Manual in Microbiology	1	5	2	2	0	0	10	1.50
Laboratory Manual in General Ecology	0	1	6	7	0	0	14	2.43
TOTAL	13	25	12	10	0	0	60	1.32
% (rounded-off)	22	42	20	17	0	0		

Legend:
Level 0 – Non-inquiry (Worksheet type)
Level 1 – Confirmation
Level 2 – Structured inquiry
Level 3 – Guided Inquiry
Level 4 – Open Inquiry
Level 5 – Authentic Inquiry

Sixty exercises were analyzed in Biology. Based on the above table, confirmation experiments constitute most (41.67%) of the activities/exercises contained in the four biology laboratory manuals sampled analyzed. There is almost an equal number of non-inquiry activities and structured inquiry activities. The highest level of inquiry in the Biology manuals is of the "guided" type, with 17% of the activities belonging to this category.

More than half of the exercises in Human Anatomy and Physiology are confirmation experiments and a third of the exercises involve non-inquiry tasks such as model or diagram study or teacher demonstrations. Examples of confirmation activities are exercises on the "Structure and Function of the Cell", and "Histology of the Skin". Examples of worksheet type activities are those on "Autonomic Division of the Nervous System". Such results are expected since anatomy is considered a dead science and the lessons do not require much inquiry activities. Inquiry activities come in mostly on the physiology component of a subject, where students may investigate the effect of certain factors on the functioning and composition of body parts. Level 2 inquiry (structured inquiry) was observed in “Physiology of Vision” while Level 3 inquiry (guided inquiry) was on “Histology and Chemical Composition of Bone”.

Meanwhile, the activities in the genetics laboratory manual are mainly confirmation (50%) and non-inquiry (33.67%), which indicates that the activities do not allow much for student independence. The expected results are provided in the introductory or background paragraphand the students will confirm whether such expected results come out in the experiment. Also, most activities include model making and confirmation of already established principles, which allow learners to practice and master skills (Buck *et al*., 2008). The highest level of inquiry is the structured type (Level 2) and is evident in the activities “Qualitative Variations” and “Observing Plant Mitosis”.

The two laboratory manuals (Genetics and Human Anatomy) have the same weighted mean (0.83), indicating that overall, they have the same degree of structure or openness.

The low level of student independence in the genetics activities could be due to the introductory nature of the course. As this is the first and only genetics course for biology education majors in the case institution, the course’s main objective is to orient and let students master the basic principles of the subject. This is where confirmation activities come in. Confirmation experiments allow students to experience well-established principles and phenomenon in a contrived setting (Banchi & Bell, 2008). As introductory genetics is one of the more conceptual and theoretical courses for Biology education majors, an understanding of its many fundamental principles is necessary for students to grasps the more advanced and applied concepts and principles in the field. Also, the case institution does not have the luxury of laboratory apparatuses that could be used in more complex topics as molecular genetics, or genetic applications. The least the teacher can do is to use physical models or films and videos in the laboratory.

In the manual in microbiology, half of the exercises are confirmatory in nature, while there is a single non-inquiry activity. The other exercises are in the guided and structured inquiry levels, in equal proportions. The exercises “Bacteriology in Water” and “Microbiology in Milk” are Level 2 inquiry (Structured), while “Soil Microbiology” and “Fermented Products” are guided inquiry (Level 3). Overall, the higher weighted mean in the microbiology laboratory activities indicates a lesser degree of structure in the microbiology manual. Such result is indicative of a higher inquiry level.

The reason for the abundance of confirmatory activities in the microbiology laboratory could be due to the complicated and meticulous procedures that characterize many microbiological processes. In microbiology experiments, students deal with microorganisms which are potential pathogens. Unless the students are well-trained in dealing with microbes, which is not the case among the science education majors, they may not be allowed to perform procedures of their own making. Microbiology exercises often involve strict protocols, and therefore, more teacher guidance and structure is required in this course.

Finally, the general ecology laboratory manual has the least structure, and therefore the greatest degree of openness and freedom to the learners. Half of the activities are guided inquiries while the other half were most structured inquiries (6 out of 7). All activities were inquiry experiments, even as one exercise is confirmatory in nature. In many of the experiments, the students are given the freedom to analyze and communicate theirresults and to state their conclusions based on what occurred in the experiments. The activity "Energy Flow Estimation from Plants to Herbivores" did not provide a hint on how data is to be analyzed, and how theresult is to be presented. Hence, it qualified under level 3, Guided Inquiry. Another level 3 exercises include "Topographic Analysis" and "Effect of pH on the Growth of Duckweed."

The inclusion of mostly inquiry activities in the ecology laboratory manual can be explained partly because of the nature of the study. There are simply so many activities and experiments in the laboratory and in the field, where students can investigate on ecological principles and theories. Students may also be flexible in reporting their results and findings in ecology.

One noteworthy trend in the analysis of the level of inquiry in the Biology laboratory manuals is the level of inquiry increases as students progressed to higher levels in their education. As they gain more experience working in the laboratory, the activities given them are gradually becoming less structured, and less teacher - guided. This is a good pedagogical practice, and is based on Vygotsky's principles of scaffolding and zone of proximal development (Wertsch, 1984). Briefly, the above notions from Vygotsky simply means that learners need more teacher guidance and structure during their initial encounter with a task. As they gain more experience, and begin to manifest some degree of independence, the level of teacher guidance and structure is gradually reduced.

Levels of Inquiry in the Undergraduate Chemistry Laboratory

The result of the analysis of the laboratory manuals used in chemistry is summarized in Table 3. As with the laboratory manuals in Biology, the titles of the manuals, the number, total, and percentages of exercises in the manual that fall under each level, the number of exercises or activities evaluated, and weighted mean of the manual as to the levels of inquiry.

TABLE 3. Levels of Inquiry in the Laboratory Manuals in Chemistry

Title of Laboratory Manual	Level						N	WM
	0	1	2	3	4	5		
Chemistry 11 Laboratory Manual and Workbook (4th Revision)	6	11	0	0	0	0	17	0.65
Organic Chemistry Laboratory Workbook	0	9	1	0	0	0	10	1.10
Biochemistry Laboratory Manual (Part 2)	1	8	5	1	0	0	15	1.62
TOTAL	7	28	6	1	0	0	42	1.023
% (Rounded-off)	17.5	70	15	2.5	0	0		

Legend:
Level 0 – Non-inquiry (Worksheet type)
Level 1 – Confirmation
Level 2 – Structured inquiry
Level 3 – Guided Inquiry
Level 4 – Open Inquiry
Level 5 – Authentic Inquiry

Forty-two Chemistry exercises/activities were analyzed in the study. The majority of the chemistry activities are confirmatory in nature. Such result is similar to the report by Buck *et al*. (2008) in their analysis that most chemistry laboratory activities are confirmation experiments. Interestingly, it was in the chemistry exercises that the three evaluators are most consistent in their ratings (r = 0.976).

The number of non-inquiry experiments and structured inquiries isalmost identical, and a single activity is rated as guided inquiry. There are no representative open inquiries or authentic inquiry activities.

The non-inquiry activities that dominate the introductory chemistry course (Chemistry 11) are mostly reminders and orientations on laboratory safety and the instruments and apparatuses used in the laboratory. Even an orientation on laboratory safety, apparatuses, skills, etc. was used as the first exercise in the manual. There was no exercises that fall in a category higher than confirmatory experiments. The confirmation activities include “The Gas Burner”, “Colligative Properties of Solutions, and “Energy and Chemical Changes”.

The result is not surprising, as the laboratory manual analyzed is also used as a workbook. As such, the manual includes worksheet - type activities that allow students to master basic calculations such as unit conversions. These skills are fundamental to understanding the mathematical nature of chemistry. Moreover, Chemistry 11 is one of the first college laboratory courses that serve as a foundation and a backgrounder for all chemistry laboratories to come. The same manual is also used by non-majors who are required to take general and inorganic chemistry as a general education course. Hence, the manual is prepared for general education purposes, not just for science education majors.

Meanwhile, ninety (90) percent of all exercises in Organic Chemistry are still confirmation activities. The expected results are stated in the exercise’s background or introduction. In some cases, the result and conclusion are even hinted in the procedure. The learners would just perform the activity as if they’re preparing a recipe from a cookbook. The activity “Preparation of Polymers: Polyesters”, is the only activity in the Organic Chemistry Manual that falls under Guided Inquiry. Incidentally, this exercise is the last activity in the manual.

The high level of teacher guidance and structure in the two beginning chemistry courses described above can be explained by nature of the discipline. Chemistry exercises deal with chemicals that can be potentially harmful. Therefore, unless the instructor have strictly considered and monitored student-designed procedures, it is not wise to give these students higher degree of independence in the laboratory.

Although most exercises in the biochemistry laboratory manual are still confirmatory, some experiments involve a relatively higher level of student independence – as structured (1 out of 3) and as guided inquiry (1 out of 15)activities. Still, these laboratory formats are structured and they do not provide much freedom, especially on how the learners analyze and communicate their results. Some examples of structured inquiry include “Qualitative test for RNA in Yeast” and “Enzymatic Browning of Fruits and Vegetables.” Meanwhile, the exercise “Isolation of Glycogen” offered the greatest degree of learner-independence, qualifying under Level 3, (Guided inquiry).

The level of inquiry in the three chemistry laboratory manuals analyzed in the study hasincreased as the learners advance in their educational level. This means that the degree of student independence in performing the activities is lower in their first chemistry laboratory, and thenteacher guidance gradually decreases as students are promoted to higher levels. This same trend, incidentally, was also noted in the Biology laboratory manuals. This means that the developers of the laboratory manuals are aware of the psychology of learning and of thelearners.

Levels of Inquiry in the Undergraduate
Physics Laboratory

Table 4 presents the analysis on the level of inquiry in the laboratory manuals in physics. Three laboratory manuals containing forty-five (45) exercises were evaluated in this study.

Table 4. Analysis of the Level of Inquiry in the Laboratory Manuals in Physics

Title of Laboratory Manual	Level						n	WM
	0	1	2	3	4	5		

Laboratory Manual in Physics 1	1	12	1	0	0	0	14	1.00
Laboratory Manual for Optics and Electromagnetism	0	11	2	0	0	0	13	1.15
Introduction to Biological and Medical Physics Laboratory Manual	2	10	4	1	1	0	18	1.39
TOTAL	3	33	7	1	1	0	45	1.20
% (rounded-off)	7	73	16	2	2	0		

Legend:
Level 0 – Non-inquiry (Worksheet type)
Level 1 – Confirmation
Level 2 – Structured inquiry
Level 3 – Guided Inquiry
Level 4 – Open Inquiry
Level 5 – Authentic Inquiry

The table above shows that the bulk of activities in all three physics manuals evaluated was meant to confirm existing physical laws or principles. These confirmatory experiments make up 73.33% of the contents of the laboratory manuals. The remaining components of the manuals are structured, guided, and open inquiry. However, three exercises are simply worksheet-like activities and hence, are not considered inquiry activities.

The contents of the laboratory manuals in introductory physics (Physics 1) range from level 0 - confirmatory (e.g. “Resultant Vectors”) to Level 2 - structured inquiry (e.g. “Law of Acceleration”), but themajority (85.7%) of the exercises are confirmatory in nature. A similar observation can be made with the optics and electromagnetism laboratory manual, although no activity is in thenon-inquiry format. Two activities (15.4%) are structured in nature. In these activities, the laboratory manual provides theproblem, procedures, and analysisby which students can discoverrelationships or reach conclusionsthat are not already known fromthe manual.

The only open-inquiry activity so far was seen in the laboratory manual Introduction to Medical and Biological Sciences. This experiment allowed students to design their investigations. In this activity, which is titled “Energetics of Long Jump”, the students are provided the problem and the theory. They are asked to design their procedures and are allowed to interpret then communicate results on their own. This open-inquiry procedure promotes intentional learning by requiringstudents to generate their own questions, plans, and goals. There is greater student involvement, and the students would gain more confidence in their ability to achieve, and therefore, they better motivated to learn and achieve more. Meanwhile, the experiment "Investigating the Mechanism of Hearing", is an example of a Level 3 inquiry.

On the laboratory manual on Optics and Magnetism, the highest inquiry levels fall under structured inquiry. These experiments allowed students to investigate the use of the scaling law to increase strengths of materials and to use the graphical method to determine the image formed by lenses.

Overall, the results of the analysis and evaluation of the levels of inquiry in the laboratory manuals in the three specific subject areas indicate that more than half of the exercises and activities are confirmation experiments. In all of these exercises, all six components of a laboratory exercise are provided for students. The problem, procedure, analysis, and correct interpretations of the data are immediately obvious from statements and questions in the laboratory manual. Confirmation experiments include activities where students observe or experience an unfamiliar phenomenon, or learn a particular laboratory technique. The results show that the number of exercises decreased as one progresses toward a higher level of inquiry, *i.e.,* from a more structured to a less structured format. Refer to Table 5 for the overall evaluation of the levels of inquiry in the laboratory manuals.

Table 5. Overall evaluation of the level of inquiry in the laboratory manuals in the three science disciplines (n = 147)

Level of Inquiry	Biology (n = 60)	Chemistry (n = 42)	Physics (n = 45)	TOTAL	~~%~~
Level 0 - Non-inquiry	13	7	3	23	15.65

Level 1 – Confirmation	25	28	33	86	58.50
Level 2 - Structured Inquiry	12	6	7	25	17.01
Level 3 - Guided Inquiry	10	1	1	12	8.16
Level 4 - Open Inquiry	0	0	1	1	0.68
Level 5 - Authentic Inquiry	0	0	0	0	0.00
Weighted Mean	1.32	1.02	1.20		

It can be gleaned from Table 5 that a little more than 91.16% of the activities in laboratory manuals fall in levels lower than guided inquiry. Among these lower ranked levels, confirmation experiments are the most common. This result conforms that of Buck, et *al*. (2008) who reported that over 90% of the inquiry activities contained in undergraduate science laboratory manuals fall below the level of guided inquiry. There was a single exercise involving open inquiry, and no activity involved a form of authentic inquiry.

The reason for providing a greater degree of structure in laboratory manuals is convenience on the part of the instructors, especially when it comes to grading laboratory results and reports. The format is advantageous to the instructor since there is a uniform format for everyone to follow. This would definitely be more convenient, since in the Philippines, especially in state-run Colleges and Universities, instructors are required to teach 21 units, with over 50 students enrolled in a class. Grading unstructured science reports would be too tasking in the part of the teacher.

When the laboratory manuals from the three science disciplines are compared in terms of their overall level of inquiry, the activities in Biology is the highest, followed by physics, then chemistry. The differences, however, are not large enough to be considered significant (p = 0.787, Kruskall-Wallis H) Again, such distinctions have nothing to do with the complexity of the activities included in the manuals. Rather, it simply implies that the activities in the Biology manual offer greater degree of student freedom and lesser amount of teacher guidance. Such differences can be attributed to the nature of the discipline, and the concern for laboratory safety or even on the ethics of experiments.

One common trend that can be gleaned from the result of this study is that in the three specific science areas, the level of openness increase as the concepts become more complex (and the students become exposed to more laboratory experiences). This observation is particularly true in chemistry and in physics. One should therefore expect more structure and less openness in the introductory chemistry and physics courses. This trend arrangement is quite natural since the students must first be allowed to experience conducting investigations or practice specific inquiry skills before they are asked to employ less structured procedures later in the course. Although confirmation and structured inquiries are considered lower-level inquiries, they are important because they enable students to gradually develop their abilities to conduct more open-ended inquiry (Banchi & Bell, 2008).

The results of this analysis on the level of inquiry in the undergraduate science education laboratory of the case institution complement the report of Buck,*et al*. (2008). In their report, the researchers found that although many recently published laboratory manuals incorporate advances in science such as novel concepts, different instruments, and new techniques, these were not accompanied by a corresponding shift in pedagogy to incorporate inquiry. The analysis of 386 individual laboratory activities revealed that the vast majority of the experiments were highly structured Level 0 or Level 1 laboratories.

The results of this study may have some interesting implications to the K – 12 science education framework in the Philippines, where an increase in the level of inquiry in particular and scientific literacy, in general, are the paramount concerns and are utmost desired (DepEd, 2012). While the choice of instructional approach, method or strategy depends on the nature of the subject matter, theintended learning outcomes, the developmental levels of students, the availability of laboratory apparatuses, among others, efforts must be made to incorporate more inquiry-based activities in the laboratory. Laboratory exercises may also be modified to foster higher level of learner independence and reduced teacher guidance. This way, laboratory activities become more authentic and meaningful in the part of the learners.

The result of the study seems to indicate that college faculty teaching science to future science teachers give lesser importance on student independence in working in the science laboratory. It appears that many science professors in college prefer laboratory activities that are highly structured over those that have more open, less-structured formats.

Since many of the laboratory courses analyzed in this study are introductory to more advanced science courses, the result seem reasonable enough. Added to this are the perennial problems of large class size, overloaded faculty, and lack of science laboratory equipment. However, while the dominant formats (confirmatory and structured) are much more convenient in the part of professors, and perhaps to some students, such formats do not offer many opportunities for the learners to be more creative and innovative in terms of designing their own procedures, analyzing their own data, or presenting the results of their investigation. As a result, the benefits of inquiry learning may not be fully explored. Also, since the format/template of the laboratory results are indicated in the laboratory manuals, the learners are not given many opportunities to practice writing scientific reports, which are less structured. This is definitely not helpful to the future science teachers who are expected to conduct studies for professional advancement, or mentor students as they conduct science investigations.

The purpose of the rubric used in this study simply denotes the extent to which a laboratory investigation provides guidance in terms of the six components. It did not attempt to classify the experiments in terms of the complexity or according to the cognitive levels they represent. The study does not necessarily imply that confirmation experiments, and even non-inquiry activities included in the manual, are not meant to develop inquiry and process skills among the students. These forms of activities or exercises, in fact, enable learners to master fundamental skills inherent in science. Also, the study does not imply that we can increase the level of structure in science laboratory manuals by removing some of the components, such as result communication and analysis, or even the procedures or design. Instead, to engage students with less structure, science instructors can modify non-inquiry and confirmation experiments to incorporate "higher" levels of inquiry. This way, college science professors can better prepare future teachers who will handle and accept the challenges set in the K – 12 science education reforms.

CONCLUSIONS

Based on the results, the following conclusions are drawn:

1. The majority of the laboratory activities provided by undergraduate college instructors, especially those designed for and used by science education majors are highly structured.
2. Confirmation or verification experiments are the dominant forms of exercises and activities in the undergraduate science laboratory manuals. This observation is particularly true in the introductory science courses.
3. The levels of inquiry in the laboratory manuals in the three science disciplines improved as students are promoted to higher educational levels.

4. The result of the study provides an important implication on the preparation of science teachers who will be handling science education at the K-12 levels.

RECOMMENDATIONS

Based on the results, this paper recommends the following:

1. Existing exercises in the form of non-inquiry or confirmation may be modified so that these exercises allow more freedom and creativity in the part of the learner. With lesser guidance, students have better ability to innovate and use heuristic skills to solve everyday problems.

2. Prospective science teachers should be exposed to more inquiry activities in their science teaching preparation course. Professors in science and education should collaborate so that the teaching of content by science professors will be infused with pedagogical innovations appropriate to science education in the K–12 levels.

3. Other researchers and teachers may use the rubric used here as a well-defined means of communicating with each other in the literature, thereby, avoiding the confusion that currently permeates literature with varied uses of inquiry.

4. The use of the rubric used in this study may offer a method for stakeholders to critically evaluate laboratory manuals, in order for them to make data-driven decisions and ultimately, to drive changes in existing curricula in science education.

5. Other researchers may venture towards a more in-depth analysis of contingency tables in reference to similar data on inquiry-based learning and teaching using manuals.

ACKNOWLEDGMENTS

The author would like to acknowledge the valuable assistance offered by Professor Judith N. Cuntig and Dr. Olga B. Betide. Their evaluations were used to determine the reliability of the ratings provided by the researcher. Gratitude is likewise accorded to the science education majors who lent some of their laboratory manuals and for providing pertinent information relevant to the study.

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