Analysis of Laboratory Activities in High School Biology Textbooks Used in China and Korea

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The purpose of this study was to examine laboratory activities incorporated in high school biology textbooks used in China and Korea. Laboratory activity is a major source of student investigation which both of the national curriculum standards strongly emphasize for achieving scientific literacy. The laboratory activities were analyzed with regard to inquiry level and science process skills. The results show that the majority of the laboratory activities analyzed were at low levels of inquiry. However, the Chinese texts provided a few laboratory activities characterized as more open, whereas none of the laboratory activities in the Korean texts was determined at more than level 3 inquiry. The Korean textbooks provided more monotonous science process skills, compared with their Chinese counterparts. One of the reasons why the texts of both nations had a high proportion of low level inquiry might be that they, as a great merit of inquiry learning, are placing more of an emphasis on effective learning of scientific concepts than cognitive development and scientific reasoning.

Introduction

Science educators continue to suggest that school science laboratories have the potential to be an important medium for the instruction of central conceptual and procedural knowledge and skills in science, and express that uniqueness of the laboratory lies principally in providing students with opportunities to engage in processes of investigation and inquiry (Hofstein and Lunetta, 2004). It is commonly quoted that science teaching must take place in the laboratory as science simply belongs

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there as naturally as cooking belongs to the kitchen. This creates the impression that there are certain things that are better learned in the laboratory than anywhere else. These are relevant and practical science skills that scientists employ in doing science (Emereole, 2009).

Both the Chinese 8th National Biology Curriculum Standards for High School (CBCS) and the Korean 7th National Science Curriculum Standards (KSCS) strongly promote the use of an inquiry-oriented approach in biology instruction which emphasizes problem solving and critical thinking in a real-world context. They both advocate inquiry in order for all students to foster scientific literacy. In this context, it is important to investigate laboratory handbook, because laboratory activity is one of major sources of “inquiry” in a science classroom, and laboratory handbook plays a vital role for most teachers and students in defining goals and procedures for laboratory activities.

Defining inquiry and assessing how much inquiry is supported by a particular laboratory activity can be difficult and confusing (Bell et al., 2005). The concept of different levels of inquiry was first described by Schwab (1962). Recently, Bell, Smetana, and Binns presented a modified framework to assess the level of inquiry, based on the amount of information provided to the student.

Science process skills are the sequence of events that are engaged by researchers while taking part in a scientific investigation. Science educators hold the belief that the acquisition of these skills will better enable students to solve problems, to learn on their own, and to appreciate science (Chiappetta, 1997). The process skills are classified into basic process skills and integrated process skills. The basic skills are the prerequisites to the integrated process skills, they provide the intellectual groundwork in scientific inquiry. The integrated skills are the terminal skills for solving problems or doing science experiments (Beautmont-Walters & Soyibi, 2001).

The purpose of this study was to examine (a) the levels of inquiry for the laboratory activities incorporated in high school biology textbooks used in China and Korea; and (b) the science process skills they covered in their laboratory activities. This investigation sought to answer the following questions:

1. Can the students of both nations be expected to progress gradually from lower to higher level inquiry investigations over their years of high school?
2. Can the laboratory activities of both nations help students develop science process skills to conduct inquiries, including higher level

inquiries?

Methods

Data Sources

Four textbooks were used in this study. All of their laboratory activities were provided within textbooks, without a companion laboratory manual. Science 9, despite being a textbook for middle school, was also included because it is the only subject provides Mendelian genetics in the secondary education of Korea.

Title	Author	Publisher	Year	Code
Chinese texts				
Biology 1-3	朱正威/ 赵占良	People's Education Press	2007	Renmin
Biology 1-3	吴相钰/ 刘恩山	浙江科学技术出版社	2005	Zhejiang
Korean texts				
Science 9	Lee et al.	Kumsung Publishing Co	2008	Kumsung
Science 9	Lee et al.	Jihak Publishing Co.	2008	Jihak
Biology II	Park et al.	Kumsung Publishing Co.	2009	Kumsung
Biology II	Lee et al.	Jihak Publishing Co.	2010	Jihak

The textbooks selected for analysis were those widely used in each country.

Five topics in the four textbooks were selected for this study, because they not only were regarded as fundamental concepts in high school biology, but also were determined to be important by high school biology teachers (Stewart, 1982).

- Photosynthesis
- Cellular respiration
- Mendelian genetics
- Cell division
- DNA

Analysis of Inquiry Levels

Invitations to inquiry exist in varying degrees. Different levels of inquiry, the concept of which was first described by Schwab (1962), can be classified depending on the level of openness (Bell et al. 2005; McComas 2005; NRC 2000). An instrument, revised by Bell et al., describes a simple model that includes four inquiry levels varying in the amount of information provided to the student. The lowest level is defined by strongly teacher-directed instructions given to the student. At the highest level, all stages of inquiry remain ‘‘open’’—the student must ask an inquiry question, choose methods, and find a solution, the four levels of inquiry are: confirmation inquiry, structured inquiry, guided inquiry, and open inquiry (Bell et al., 2005, see Table 1). This study used this framework for evaluating laboratory materials.

The character of laboratory activity can be classified as follows: wet labs in which students use materials and equipment, while paper and pencil activities that are dry labs, where students do not use materials or equipment (Germann et al., 1996). In this study, the analysis of inquiry level was confined to the “wet labs”.

Table 1 Four-level model of inquiry produced by Bell et al.

Level of inquiry	Question	Methods	Solution
1 (confirmation)	X	X	X
2 (structured)	X	X	
3 (guided)	X		
4 (open)			

Note. The X marks what is provided by the teacher

Analysis of Science Process Skills

Most commonly cited science process skills are observing, classifying, space/time relations, using numbers, measuring, inferring, predicting, defining operationally, formulating models, controlling variables, interpreting data, hypothesizing, and experimenting (Chiappetta et al., 1998). This study included more process skills for a detailed analysis of the laboratory activities in the four textbooks of China and Korea. Table 2 presents a list of science process skills examined in this study. Not only wet labs but also dry labs were examined in this analysis.

Table 2 Science process skills

Process Skill	Code	Definition
Observing	1	-noting the properties of objects and situations using the five senses
Classifying	2	-relating objects and events according to their properties or attributes
Measuring	3	-expressing the amount of an object or substance in quantitative terms, such as meters, liters, grams, and newtons
Calculating	4	using quantitative relationships
Inferring	5	-giving an explanation for a particular object or event -drawing conclusions about the result(s) of an observation or experiment.
Predicting	6	-forecasting a future occurrence based on past observation or the extension of data
Judging about experiment	7	-interpreting/explaining/making a decision about experimental technique
Recording results	8	-recording, describing or drawing results verbally, in writing, or by drawing pictures, filling out blank cells from table
Manipulating apparatus	9	-selecting appropriate materials for the experiment to be done and set up the experimental apparatus accordingly.
Transforming data	10	-transforming data into graphs and tables
Interpreting data	11	-arriving at explanations, inferences, or hypotheses from data that have been graphed or placed in a table; -interpreting data statistically; -identifying human mistakes and experimental errors
Identifying/ Posing	12	-identifying questions to be answered or problems to be solved

questions		

(table continues)

Process Skill	code	Definition
Formulating hypothesis	13	-stating a tentative generalization of observations or inferences that may be used to explain a relatively larger number of events but that is subject to immediate or eventual testing by one or more experiments
Identifying/ Controlling variables	14	-determining all the variables in an experiment, for example, the dependent, independent, and controlled variables -manipulating variables during experimentation
Designing an experiment	15	-designing an experiment by identifying materials and describing appropriate steps in a procedure to test a hypothesis
Drawing conclusions	16	-formulating conclusions
Formulating models	17	-constructing images, objects, or mathematical formulas to explain ideas
Reporting/ Communicating/ Arguing	18	-communicating to share their observations with someone else, giving a presentation on the experiment, try to convince someone by laying out a logical basis
Evaluating	19	-evaluating experimental design -recommending further testing where necessary
Experimenting	20	-carrying out an experiment by carefully following directions of the procedure so the results can be verified by repeating the procedure several times.

Results

Overview of Laboratory Activities

Examining of the inquiry activities in the textbooks shows that there is a distinct difference between the two nations. Table 3 and Figure 1 depict the distribution of wet and dry labs. The most outstanding feature is that the Korean textbooks offered more dry labs (i.e., paper and pencil tasks) than wet labs. In contrast, the Renmin contained 69% wet labs, and the Zhejiang designed most of their inquiry activities in the form of wet labs. One of the reasons why Korean textbooks have higher percentage of dry labs, in other words, reducing the number of wet labs which require much time, might be that wet labs can be burdensome for both students and teachers, because the main targets of Biology II are the students of science stream and they usually take the course in their last year of high school, when they have to prepare for university entrance examination.

Table 3 The distribution of wet and dry labs

Textbook	Number of laboratory activity		
	Wet lab	Dry lab	Total
Renmin	9	4	13
Zhejiang	9	1	10
Kumsung	4	13	17
Jihak	8	12	20

However, more time-consuming is not likely to be a conceivable reason for many dry labs of the Korean texts, because the topic of Mendelian genetics which students learn in the third year of middle school, regardless of publisher, also had more dry labs. A more convincing explanation for the high frequency of dry labs in the Korean texts is as follows. Most textbook publishers are not free from pages limits, although “inquiry” is extremely stressed in their curriculum, so they reorganized the knowledge contents, which are usually in the form of descriptive explanations in the Chinese texts, into the format of dry labs under the title of “Inquiry”. The dry labs, in many cases, covered many famous experiments throughout the history of biology, where students were asked to answer about the experiment, such as predict the result, interpret data, and draw conclusion. Students were expected to develop their inquiry skills by participating in the process of experiments scientists conducted in the past. The form of dry labs made the publishers of the Korean textbooks find a compromise between "inquiry" and pages limits.

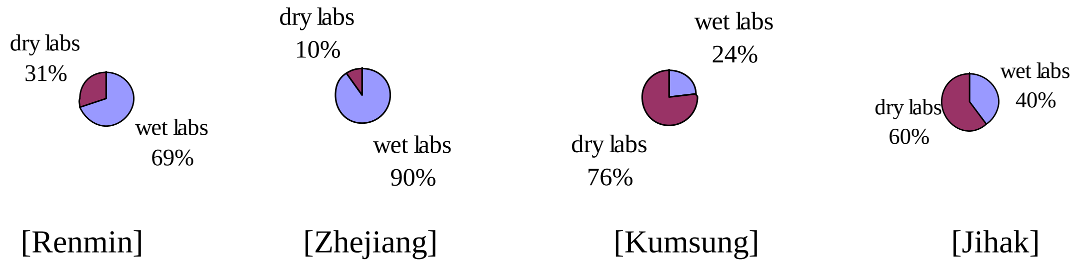

Fig. 1 The distribution of wet and dry labs

Analysis of Inquiry Levels

Table 4 shows the inquiry levels of the wet labs in the five topics. The findings from the determination of the inquiry levels indicate that majority of the laboratory activities in the five topics invited students to participate in low levels of inquiry. Most of the wet labs were either level 1 confirmation or level 2 that defined the problems students need to investigate and provided step by step procedures to follow. None of the laboratory activities provided in the Kumsung or Jihak was determined at more than level 3 inquiry. It means that there was no opportunity for students to choose their own problem to investigate and to design their own procedures. In contrast, students, although not very often, are allowed to have greater responsibility in the Renmin and Zhejiang: a few laboratory activities were determined at level 3. But unlike the Zhejiang, the level 3 activities of the Renmin attached a couple of examples of designing an experiment including its procedures as references by which students can be guided, therefore it is likely that the activities is bound to drop to level 2 in the actual classroom practice, rather than level 3 which probably is the original intent of the textbook author. The level 3 inquiries in the Chinese textbooks organized students' investigation in small groups. Different groups of students began with a testable question which was posed by the author. They approached the question by testing different independent variables, for example, each group was asked to investigate different factors affecting the rate of photosynthesis, formulate hypothesis, and then design their own procedures. Students need to share their findings with peers, when they have class presentation. Students can develop teamwork skills through such a small group activity: Assign tasks and trust their partner’s skills; Identify and utilize the strengths of each team member; Practice working as a team and perfecting proper techniques and procedures.

Table 4 Evaluation of levels of inquiry for wet labs presented in the five topics

	Levels of inquiry			
Topics of laboratory activity	Ren-min	Zhe-jiang	Kum-sung	Ji-hak
Cellular respiration				
Alcoholic fermentation in yeast		(De)	2	
Cellular respiration in yeast	3*			
Measuring respiration rate				2
Photosynthesis				
Separating leaf pigments	2	2		2
Effect of light intensity on photosynthesis				2
Effect of environmental factors on photosynthesis	3*	3		
Mendelian Genetics				
Simulation of monohybrid cross	1	1	1, 1[c]	1
Simulation of dihybrid cross		2		
Simulation of dihybrid test cross		1		
Cell Division				
Investigating the limits of cell growth	2			
Observing mitosis	1	2[a],1[b]	2	2
Observing meiosis	1			2
Simulating chromosome behavior in meiosis	2	2		
DNA				
DNA extraction				2
Constructing a model of DNA	N/A	N/A		1

Note. De = Demonstration; [a] observing permanent slides of mitosis; [b] making a temporary mount of onion root tip for mitosis; [c] Computer-based; * indicates a laboratory with a specific example to guide students; N/A refers to activity not appropriate to be classified: What is open to students in constructing a model of DNA is only procedure, while question and the answer are provided.

Analysis of Science Process Skills

Table 5 presents the frequency of science process skills, and Figure 2 shows this information in bar chart. The process skill ranked at number one, if we leave the skill of manipulating apparatus out of consideration, is different between two countries, and this is a natural consequence caused by the difference of their main type of laboratory activities. The major form in dry labs which are frequently seen in the Korean textbooks is that students are given a set of data with a graph or a table first and then asked to answer cause and effect relationship, to make prediction or inference based upon the data. The process skill that is most often found, therefore, was analyzing/interpreting data. On the other hand, Chinese textbooks with more wet labs ask students if they understand the results of the experiment, so it is natural that the process skill “recording/describing/drawing results" took the first place. These two process skills (i.e., recording/describing/drawing results and analyzing/interpreting data) are commonly found across the Chinese and Korean textbooks, except that rarely are students required to use the skill of analyzing/interpreting data in the Zhejiang.

The Korean textbooks offered the skill of analyzing/interpreting data in easier ways, in other words, they asked students to use “lower order” analysis skills (e.g., determining qualitative and quantitative relationships within the data), while Renmin provided higher level skills (e.g., interpreting data statistically, identifying experimental errors).

Besides those skills, students of both nations are often asked to perform inferring and interpreting/explaining/making a decision about experimental technique or procedures. Although the KSCS emphasizes team work skills and communication in the inquiry activity, none of the Korean textbooks examined in this study reflected their curricular objectives, whereas these skills were not neglected in their Chinese counterparts. The Renmin asked students brief discussion about results of experiments, and some argumentation while designing an experiment in their level 3 laboratory activities as well as dry labs. The communication skills offered by the Zhejiang included the skills of expressing what students learned after their experiment and reporting to their classes (you can see this in their level 3 laboratory activities or in the constructing a model of DNA where each student use his/her own materials).

The integrated process skills such as formulating hypotheses, controlling variables, designing experiment, and experimenting were extremely rare in the Chinese textbooks, and almost zero in the Korean textbooks. The process skill of formulating models could not be found anywhere in the textbooks of the two nations.

Table 5 The frequency of science process skills

Code	Science process skills	Ren-min	Zhe-jiang	Kum-sung	Ji-hak	Code	Science process skills	Ren-min	Zhe-jiang	Kum-sung	Ji-hak
1	observing	2	5	1	5	11	interpreting data	5	2	10	15
2	classifying	0	0	1	0	12	identifying questions	2	0	1	0
3	measuring	1	0	0	1	13	formulating hypothesis	1	1	0	0
4	calculating	5	3	2	4	14	controlling variables	1	1	0	0
5	inferring	5	4	11	13	15	designing an experiment	3	1	0	0
6	predicting	2	1	1	4	16	drawing conclusion	5	2	2	1
7	judging	8	6	6	8	17	formulating models	0	0	0	0
8	recording results	12	10	8	9	18	communicating	4	3	0	0
9	manipulating apparatus	15	12	10	31	19	evaluating	2	2	0	0
10	transforming data	2	2	0	0	20	experimenting	2	1	0	0

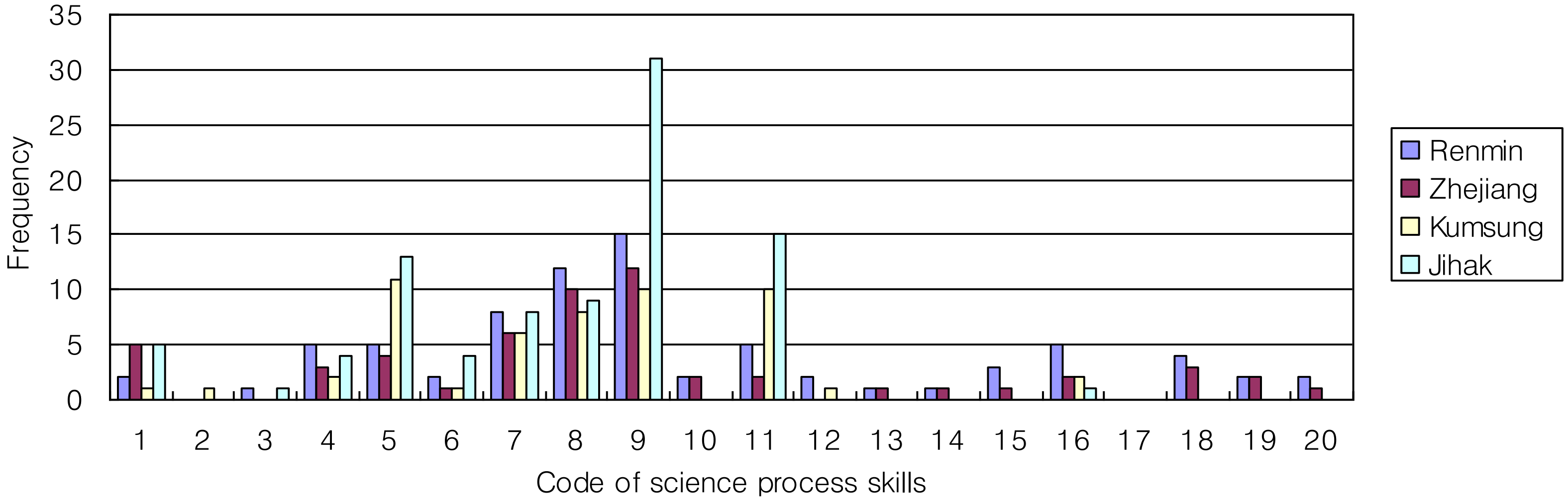

Fig. 2 The distribution of science process skills

Discussion

Analysis of Inquiry Levels

As the result of the analysis of inquiry levels have shown, most of the laboratory activities of the four textbooks are at lower levels of inquiry. Although the laboratory activities examined in this study are only a small part of the whole, they are not insufficient to notice the textbook's trend.

Educators typically employ laboratory activities in the science classroom in the service of the goals, and one of them is deep understanding of the knowledge of science. Guided inquiry can best focus learning on the development of particular science concepts, while more open inquiry will afford the best opportunities for cognitive development and scientific reasoning (NRC, 2000). Both the CBCS and KSCS consider the understanding of scientific knowledge as a great merit of inquiry learning, as noted in the analysis of the CBCS and KSCS (Kim, 2011). Therefore, it is not surprising that there are so many level 1 and level 2 laboratory activities in the four textbooks. The authors of the four texts, in this sense, faithfully reflected their curriculum intent.

The learning about nature of science and scientific inquiry is also the crucial objective of the laboratories (Germann et al., 1996). Science educators are continually searching for innovative ways to encourage students to conceptualize the dynamic and ever-changing nature of the scientific process, via a complex, ill-structured inquiry learning process, that is, open inquiry (Sadeh & Zion, 2009). The problems and procedures given in lower level inquiries, which were very common type of laboratory activities in the Korean textbooks, may surround students with a sense of certainty that does not always exist in science. In this context, the lack of higher level inquiries should be recognized as a serious problem in terms of students' understanding of nature of science and scientific inquiry. Therefore, the fact that none of laboratory activities were more than level 3 in the Kumsung or Jihak might be partly due to the lack of emphasis on this point in the KSCS.

The Korean revised curriculum which is a modification of the KSCS has just begun to be implemented in the 1st grade of high school in 2011. It placed special emphasis on "creativity", which is the feature discriminated this revised curriculum from those curricula before. A creative individual is not afraid of failing, takes risks, and seeks the unknown. Creativity involves a novel approaches to problems. In this respect, laboratory activities exclusively with lower level inquiries where all students conduct an experiment with the same design and same procedures, and their experimental results are predictable and clear might do students more harm than good concerning sparking their creativity. Students need to be guided to the high-level inquiry investigations after having participated in low level activities.

Analysis of Science Process Skills

The acquisition and frequent use of science process skills can better equip students to solve problems, learn on their own, and appreciate science (Chiappetta, 1997). The CBCS devotes a lot of space to science process skills in its objective and the KSCS also emphasizes them, although in somewhat unsystematic way. Laboratory handbooks are the mediators between curricular intention and classroom implementation in terms of students' inquiry activities. As the results have shown, the Chinese textbooks tried to reflect their curricular goals: they covered most of the process skills examined in this study, while there existed a serious imbalance in the distribution of these skills in the Korean textbooks.

The fact that the Korean textbooks, for training the skill of analyzing/interpreting data, assigned students monotonous tasks is problematic. They required students to determine qualitative or quantitative relationships within the data repeatedly. Although the course of Biology II is for science stream students who are potential producers of new scientific knowledge, the students, however, are consumers of scientific information at the same time— Miller, the English science educator, borrowed these economic terms in his article (2008). The students counter inevitable deluge of experimental data in everyday life, they read and hear biology related news, such as health and environment. For better informed consumers of scientific information, science educators need to help them develop more diverse process skills about data interpretation, for example, identifying human mistakes and experimental errors, understanding the difference between a statistical correlation and a genuine causal link, recognizing data and its limitations, and so on.

The KSCS places emphasis on "discussion" for democratic citizenship (Kim, 2011). This aspect is also important in the understanding of the nature of science: scientific rationality is grounded not only in procedures of inquiry but also in debate and argumentation within scientific communities (Knain, 2001). However, the Korean textbooks did not reflect this objective for students' scientific literacy as future adults. The lack of communication/argumentation skill could be caused by lower level inquiries which make up the majority of laboratory activities in the two Korean texts. The lower level activity is highly teacher directed, that is, a large amount of information is provided to the student, for this reason, there is no room for students' discussion or argumentation. As we have seen in the cases of the Chinese textbooks, giving students an opportunity to design their own experiment in pairs or in small groups may be a suitable way to enhance the skills of communicating/reporting/ argumentation, because they have to meet and discuss their design, report results in front of the whole class, and if necessary, argue for relative merits of their design.

The Renmin and Zhejiang directed students to practice integrated process skills, such as, formulating hypothesis and controlling variables, but only in the level 3 inquiry activities. Unless students have had enough training to develop these skills through the other inquiry activities like paper and pencil tasks before, it may be difficult for them to perform those process skills.

Science educators in Korea have been pointed out that many of their textbooks where students were not required to the higher order process skills are a big problem. The integrated science process skills are crucial skills for solving problems or doing science experiments. For instance, formulating hypothesis is an important facet of scientific inquiry because it enables us to create useful representations of real world objects, resolve anomalies, and develop new theories (cited in Oh, 2010). By forming hypotheses about natural phenomena, the ideas students have that influence how they learn are exposed, making the correction of their misconceptions feasible (cited in Mitchell, 2007). In terms of controlling variables, the ability to correctly use this skill is central to scientific reasoning in planning experiments and in interpreting their results because the basis of it is the understanding that good experimental design relies on changing only one variable at a time, while the other variables are kept constant in order to identify cause and effect (Babai and Dori, 2009).

None of the laboratory activities in Kumsung and Jihak directed students to challenge the integrated process skills might raise concerns about the effectiveness of "free inquiry" included in the revised curriculum which was just implemented from 2011. So-called "free inquiry" is an open inquiry activity in which students design their own procedure to carry out the investigation on their own topics. It is adopted in the hope of developing students' interest in science and enhancing their creativity. However, it is unlikely that underprepared students can properly perform such a high level of inquiry.

In short, some discrepancies between curriculum objectives and the textbooks in terms of inquiry can be seriously taken into consideration by science educators of the two nations. There is no question that the laboratory activities should give students opportunities to perform the tasks demanding a variety of science process skills, to challenge higher order process skills as they go to higher grades, that is, laboratory activities in the textbooks should be organized systematically in terms of the degree of difficulty, start with basic process skills and then move on to integrated skills progressively.

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