A Project entitled

Students' Perceptions on Science Process Skills Development during Biology Lessons

Submitted by

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Declaration

I, ***Chan Nok Yin*** , declare that this research report represents my own work under the supervision of ***Senior Lecturer Dr. Lee Hoi Man, Sarah***, and that it has not been submitted previously for examination to any tertiary institution.

Signed:

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Abstract

The thinking skills involved in scientists' construction of knowledge are known as science process skills (SPS). Owing to the importance of SPS, this set of skills is included as part of the science education curriculum worldwide. In Hong Kong, teachers are recommended to implement different teaching and learning strategies in class to booster students' development of the 6 essential SPS (i.e., "Observing", "Classifying", "Designing Investigations", "Conducting Practicals", "Inferring", "Communicating") stated in the curriculum. Nevertheless, little is known about students' SPS development during science lessons in Hong Kong, particularly, Biology lessons under the Hong Kong Diploma of Secondary Education (HKDSE) curriculum.

This study examines the most and the least developed SPS as well as the development of SPS in Biology lessons from students' perceptions in the Hong Kong context with the qualitative approach. Data collection consisted of questionnaires, focus group interviews and individual interviews. 21 students were first invited to complete a questionnaire. Upon the completion of questionnaire, 12 students were invited to take part in the focus group interviews, and eventually, 6 students from the 12 students were invited to participate in the individual interviews.

Thematic analysis was then applied in analyzing the transcripts of the interviews.

Findings from the study suggest that (1) students tend to have different perceptions on their most and least developed SPS in Biology lessons though some of them regard the same SPS as their most or least developed SPS, and (2) students have developed SPS during their Biology lessons under the instructional approaches adopted by their teachers. These findings could serve as a reference and provide insights for teachers in their instructional design so as to better cater students' SPS development in Biology lessons.

Keywords: Biology Education, Science Education, Science Process Skills Development

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Table of Contents

List of Tables

Chapter 1 – Introduction

1.1 Research Background

Science process skills (SPS) are the thinking skills involved during scientists' construction of knowledge in order to tackle problems, express ideas, work out results, and exchange information (Chiappetta, 1997; Özgelen, 2012). These skills are important to students as they benefit students a lot in terms of students' learning and their scientific literacy. It is suggested that SPS are the foundations of using scientific methods to acquire new knowledge and develop prior knowledge, in which these skills could be further applied to problems in daily lives (Millar, 2015; Kusuma et al., 2020). In the meantime, Gultepe (2016) highlights that the skill enables individuals to become scientifically literate with its application.

Due to the importance of SPS in facilitating students' learning as well as developing students' scientific literacy, many countries and regions, including Hong Kong, have included SPS as a component of the science education curriculum, e.g., (The Curriculum Development Council [CDC], 2017a). In Hong Kong, teachers' role in facilitating students' SPS development is emphasized by the Education Bureau, which teachers should implement various learning activities to develop students' SPS (CDC, 2017a). Furthermore, students' SPS development has become increasingly important in Hong Kong as evidenced by the stronger emphasis of students' SPS development in its updated science education curriculum (CDC, 2015).

1.2 Problem Statement and Research Question

Although various studies on how students develop their SPS during lessons have been carried out in different parts of the world, only a few relevant research has been conducted in Hong Kong, especially for students' SPS development under the HKDSE Biology curriculum. Therefore, it is questioned that how do students in Hong Kong develop their SPS during their Biology lessons. Furthermore, little is known about students' perceptions on their most and least developed SPS.

Since students' perceptions are powerful indicators for determining the effectiveness of teachers' instruction in class (Den Brok et al., 2006; König et al., 2016), students' perceptions could provide insights for teachers to consider means to promote and enhance students' SPS development in their instructional design. Thus, this research looks for answers to the following research question:

1. What are the most and the least developed SPS in Biology lessons from students' perceptions in Hong Kong? How do students develop these SPS in Biology lessons from their perceptions?

Chapter 2 - Literature Review

2.1 About SPS

2.1.1 Historical Background of SPS

The term "science process skills" arises from the curriculum project "Science, a Process Approach (SAPA)" in the 1960s (Livermore, 1964; Padilla, 1990). The presupposition that underlies the project is that "complex behavior of scientists can be analyzed into simpler activities, and that these can be arranged in a hierarchy of complexity for purposes of instruction" (Nay, 1971, p.199).

In SAPA, the SPS are grouped into 2 categories of skills, the basic and integrated science process skills. The basic skills are simpler and can serve as a scaffold for students to acquire the integrated science process skills, the skills that are more complex (Padilla, 1990). The basic and integrated science process skills are summarized in Table 1.

Table 1: Basic and Integrated science process skills in SAPA

Science Process Skills	Details
Basic	● Observing ● Classifying ● Measuring ● Communicating ● Inferring ● Predicting ● Recognizing Space and Time Relations

	● Recognizing Number Relations
Integrated	● Formulating Hypotheses ● Making Operational Definitions ● Controlling and Manipulating Variables ● Experimenting ● Interpreting Data ● Formulating Models

(Livermore, 1964, p.273)

2.1.2 SPS in the Hong Kong Science Education Curriculum

Nevertheless, the basic and integrated SPS from SAPA has been combined and integrated into 6 essential SPS in Hong Kong, namely "observing", "classifying", "designing investigations", "conducting practicals", "inferring" and "communicating", and nurtured from Primary 1 to Secondary 6. Each essential SPS consists of various sub-categories (CDC, 2017b). The SPS and their corresponding sub-categories are summarized in Table 2.

Table 2: Essential SPS and their details in the Hong Kong science education curriculum

Science Process Skills	Details
Observing	● Stating characteristics ● Measuring sensibly and accurately ● Recording data
Classifying	● Comparing similarities and differences ● Grouping and ordering ● Constructing keys ● Stating relationships (including cause and effect)
Designing investigations	● Asking questions ● Predicting results ● Making hypotheses ● Identifying variables

	● Suggesting operational procedures with consideration for fair testing
Conducting practicals	Hands-on practice including: ● Choosing apparatus ● Handling apparatus ● Taking precautions
Inferring	● Analysing and interpreting data ● Evaluating data ● Estimating errors ● Constructing explanations ● Drawing conclusions
Communicating	● Using multiple representations to present information and ideas ● Putting forward logical scientific arguments

(CDC, 2017a, p.31)

2.2 Development of SPS among students

Studies on the development of students' SPS have been carried out by several researchers. Students' SPS could be developed as students conduct scientific investigations and through their learning process with appropriate and adequate guidance (Harlen, 1999; Ango, 2002, CDC, 2017a), in which various teaching and assessment approaches could be adopted for such purpose, including discussions, guided-inquiry, open laboratory inquiry, students' presentation (Roth and Roychoudhury, 1993; Rauf et al., 2013; Pulungan et al., 2021) and formative assessments (Grob et al., 2017; Ganajová et al., 2021). These studies have shown that students' SPS could be developed through the teaching and assessment approaches adopted by teachers during lessons. The enrichment of students' SPS development by these approaches could be

attributed to students taking a leading role in their learning in these approaches, which they have more opportunities to practice and utilize their SPS with more exposure to tasks involving the application of SPS, e.g., (Idul et al., 2022).

Meanwhile, various studies have been conducted to investigate the actual enrichment of students' SPS in class. It is found that students have experienced enrichment in their SPS through their lessons. For instance, the research by Idul and coworkers (2022) have found that students have demonstrated mastery in their "observing", "classifying" and "inferring" skills in their lessons involving elements of inquiry-based learning which students have to apply their SPS. Nevertheless, there are some SPS which students have exhibited little or minimal development in class. For example, the study conducted by Kusuma and colleagues (2020) have revealed that students showed low level of acquisition of "designing investigations", "inferring" and "communicating" skills as evidenced by their inability to suggest hypotheses and operational procedures, as well as interpreting and constructing graphs. The studies have suggested that although students have displayed improvement in some of the SPS, there are still some SPS which students do not show much enrichment in the real context.

Chapter 3 - Methodology

3.1 Research Design

Qualitative research approach was adopted in this study to obtain students' perceptions towards the most and the least developed SPS as well as their development of their SPS in Biology lessons. 3 research instruments, online questionnaire, focus group interviews and individual interviews were employed in this study.

3.2 Participants

The secondary school invited to participate in this study is a convenient sample which the researcher was having block practice. The school is a local Band 3 secondary school adopting the HKDSE curriculum with Chinese as the Medium of Instruction. A class of F.5 Biology students that consists of 21 students was chosen for this study because the study aims to obtain students' perceptions on the most and the least developed SPS and their SPS development in Biology lessons. Since F.5 students has around 2 years of experience in studying Biology, they are suitable for participating this research.

At the beginning of the study, permission for conducting the research in the school was obtained from the school principal and their subject teacher. The principal had signed the consent letter before inviting students to take part in the research. With the consent from the principal, the researcher had introduced the background of this research and invited the F.5 Biology students

to participate in the research. To participate in this research, students and their parents were required sign the 2 consent forms that verifies students' participation and confirms parents' permission for students in participating in the research distributed respectively.

3.3 Data Collection and Analysis

3.3.1 Online questionnaire

The online questionnaire was adopted before the focus group interviews to explore the major and minor opinions of students on the development of their SPS during Biology lessons. Lune and Berg (2017) suggest that this procedure could be regarded as a step of "extended focus group", a strategy that is commonly employed by researchers in qualitative studies. The data collected could serve as a reference for the researcher to understand the views of the participants before the focus group interview while allowing the participants to develop their stance before the interview (Sussman et al., 1991, as cited in Lune and Berg, 2017).

Thus, 4-point Likert Scale was adopted in the questionnaire, given that the 4-point scale could force participants to make decisions (Melville and Goddard, 1996). Besides, according to Sullivan and Artino (2013), Likert Scale is commonly used in educational research for measuring abstract concepts that cannot be represented with a survey item while Joshi and co-workers (2015) further suggest that Likert Scale can be adopted in researches that aim at recognizing participants' perceptions.

In the questionnaire, students were required to indicate how much they agree or disagree with the statements describing students' development of the 6 essential SPS stated in the Science Education Curriculum in Biology lessons from 1-4 (1: Strongly disagree; 4: Strongly agree). The data obtained from the questionnaire were recorded in frequency counts and percentage.

3.3.2 Focus group interviews

12 students who had attempted the questionnaire were invited to participate in focus group interviews that were semi-structured and conducted via ZOOM. They were grouped into 3 different groups, namely, the high ability group (group A), the medium ability group (group B) and the low ability group (group C). The students from the high, medium and low ability groups were selected randomly according to their position in form in their quizzes and first term test. Each student selected were given a pseudonym based on their group name (e.g., student A1 indicates student 1 of group A) to ensure their anonymity in the study.

The reason for adopting focus interviews in this study is because focus group interviews enable more ideas and information to be revealed from the participants than individual interviews, provided that "[p]articipants' statements in focus groups could be seen as stimuli for other participants to voice similar experiences or problems in the discussion" (Coenen et al., 2012, p.367). In addition, focus group interviews enables participants holding minority views to

express their views to other individuals in the same situation as themselves (Barbour, 2007).

The interview questions were devised to obtain students' perceptions towards the most and the least developed SPS in Biology lessons and the development of their SPS in Biology lessons. Besides, some individual follow-up questions were prepared for some participants whose responses were the minority in the questionnaire to facilitate a deeper understanding on the perceptions of the minority. Meanwhile, since the students selected were either native speakers of Cantonese or Mandarin, they were allowed to speak in their mother tongue; each focus group interview were audio-recorded and converted to transcripts for preliminary thematic analysis after receiving the permission from the students.

3.3.3 Individual interviews

2 students from each focus group (i.e., 6 students in total) were invited to take part in the individual interviews. The students were selected based on the quality of the responses in the focus group interviews. Pseudonyms provided during the focus group interviews were continued to be adopted in the interviews.

The rationale for implementing individual interviews in the study is because more detailed information and personal stories could be obtained from the participants via individual interviews. It is suggested that compared to focus group interviews, individual interviews are

more appropriate in eliciting the participants' experience in the specified context in greater detail (Barbour, 2007). Besides, the purpose of inviting only 6 students to take part in the interview is to prevent the saturation of ideas, in which it is found that information obtained after 6 interviews would be saturated, in which most of the information relevant to the research could be obtained after 6 interviews (Guest et al., 2020).

The interview questions for the individual interviews were designed based on the responses from participants' responses in their focus group interviews in order to achieve a deeper and more comprehensive understanding on students' perceptions towards the most and the least developed SPS in Biology lessons and the development of their SPS in Biology lessons. Similar to the focus group interviews, students were allowed to answer the questions in their mother tongue and the interviews were audio-recorded and converted to transcripts for thematic analysis.

3.4 Research Procedure

Upon the submission and approval of ethical review application, the research began in December. Consent and consent letters had been obtained and signed by the principal, students and students' parents prior to the distribution of questionnaires and conduction of interviews.

After receiving students' responses on the questionnaire, focus group interviews that had been

lasted for 30-40 minutes were arranged and the interviews were transcribed into transcripts based on the audio-recordings for preliminary thematic analysis, in which potential themes of the study were identified.

Upon the completion of preliminary thematic analysis in February, students selected for participating in the individual interviews were approached and invited to take part in the individual interviews that takes around 15-30 minutes. After the interviews, transcription was conducted based on the audio recordings for further thematic analysis. All interview data of the 6 participants of the individual interview were gathered and organized into the corresponding questions of the study and the themes identified from the data collected.

Chapter 4 – Results and Discussion

4.1 Most Developed SPS in Biology lessons

The most developed SPS in Biology lessons highlighted by students are "Observing", "Classifying" and "Designing investigations" skills. In the following, the possible reasons for these skills being the most developed and how do students develop these skills from their perceptions would be discussed.

4.1.1 Observing

Student A4 responded "Observing" skill is his most developed SPS. This might be related to the nature of the skill "Observing", resulting in the higher frequency of exposure of the skill among all topics than other skills.

"(This SPS is the most developed) because the Biology lessons during these 2 years has informed me with many features of objects…also we have been taught with many methods to take measurements… probably… the growth parameters… so overall, there are many methods to take measurements have been provided during Biology lessons, which we have learnt it."

(Student A4)

Daston and coworkers (2011) assert that "Observing" is an essential and pervasive process in learning all types of science under the scientific approach. This may suggest students would be exposed to "Observing" skills regularly as they are learning different topics of Biology in class. In addition, Kaur (1972) states that "Observing" skill is the prerequisite of other SPS, in which

the skill is the fundamentals of learning other SPS. This may imply that students may tend to expose to the skill more frequently as they master other SPS during their learning. Therefore, during Biology lessons, as the student is learning different topics of Biology and other SPS (e.g., "Conducting Practicals" skills during practical sessions), he may recurrently encounter the application of "Observing" skills. As he encounters with the skill more, he may believe he has this skill more developed than other SPS. This may in turn help to explain the reason for Student A4 choosing this SPS as the most developed in which his exposure to the skill may be comparatively more than the other SPS during Biology lessons.

It seems that the high frequency of exposure to "Observing" skills due to the nature of the skill enables it to be the most developed in Biology lessons. In fact, one of the possible sources which students expose to this skill and have this skill developed could be the provision of hands-on experience in class.

Provision of hands-on experience

Student A4 suggested that the provision of hands-on experience in making observations (e.g., observing the features of the cross-section of leaves) during lessons enabled the development of his "Observing" skills, in which he believed that as he makes more observations, his improvement in the skill could be enhanced.

"[W]e were allowed to really observe the features of the structures… our teacher has allowed us to make observations on some specimens of leaves, I mean, to observe the cross-section of leaves, and observe different cells present on the leaves, for instance, guard cells and normal epidermal cells… What are their characteristics and differences… These could be observed…I think perhaps its (Observing) improvement could be quantified… When you observe once, you may fail. However, as you observe more, you could do it…"

(Student A4)

This finding is consistent with the claims of Ango (2002) and Rauf et al. (2013) which the degree of students' mastery in "Observing" skill is positively correlated with the hands-on experiences provided for students to develop their "Observing" skills. Therefore, this supports students are able to have this skill developed through the provision of various hands-on experiences involving "Observing" skills.

4.1.2 Classifying

Students B3, C1 and C3 believed "Classifying" skill is their most developed SPS. For Students B3 and C3, the reason for this skill to be the most developed could be related to their enhanced learning motivation in learning the skill as a result of their interest in the topics related to this skill.

"It is because during the pandemic, the virus has many variants. The virus frequently varies… Therefore, I believe this skill is improved the most…Well, in fact, our Biology lessons has introduced "Classification" ... For instance, using "Minions" as an example… I mean each "Minions" have different characteristics, right? Then our teacher would ask us how to classify them…"

(Student B3)

"It is because we have done more "Classifying" than "Observing" during lessons. It is because "Classifying" is common for us to encounter in our daily lives. Therefore, I can practice the skill in my daily life."

(Student C3)

It is suggested that situations that are of personal relevance could trigger students' situational interest in relevant topics, in which the situational interest aroused could eventually facilitate students' construction of knowledge related to the situation with the provision of relevant learning activities in class (Hidi et al., 2006). For Student B3, the time which he learnt "Classifying" skills was at the time of the COVID-19 pandemic. Since there are different variants of the COVID-19 virus identified and classified throughout the pandemic, his situational interest on "Classifying" skills in his daily lives may have enhanced. Similarly, for Student C3, since the application of the skill is common in her daily lives, this may have raised her situational interest on "Classifying" skills. Since their situational interest were aroused, with the provision of learning activities related to "Classifying" skills in class, they may experience a better development on the skill and in turn believe this skill is their most developed SPS.

Meanwhile, for Student C1, the possible reason for this skill being the most developed could be attributed to the level of difficulty for acquiring the skill.

""Classifying" is comparatively improved… It is because initially my "Observing" skill is better and I like… I mean… They have different features and I think it is easy for me to classify (through observations). But others (SPS) are comparatively difficult to master."

(Student C1)

Kusurkar (2012) states that students' learning motivation would be the highest when the target is neither too easy or too difficult while Slavin (2018) suggests that students' learning motivation is positively related to students' learning outcomes. Since the difficulty of this skill is comparatively optimal and achievable to her, she might have developed a certain level of learning motivation in this skill, which in turn may have promoted her learning in the skill, and eventually causing her believing this skill is the most developed for her.

From the responses above, it is noticed that students' interest in the topic related to the skill and the level of difficulty for acquiring the skill may lead to students perceiving this skill as the most developed SPS during their Biology lessons. Indeed, the relationship between "Observing" and "Classifying" skills as well as the provision of various examples during Biology lessons may help facilitate students' "Classifying" skills development in class.

Relationship between "Observing" and "Classifying" skills

Student C1 acknowledged her development in "Observing" skills had been assisted by the development of their "Classifying" skills. She suggested that her "Observing" skills had laid a foundation in her "Classifying" skills development as she have to observe different features in order to perform classification.

"It is because I think with comparison, they must have some differences. With some differences, then we can classify what they are… And also, perhaps my "Observing" skill is comparatively better. Therefore, it is relatively easy for me to identify their difference"

(Student C1)

This finding is in line with the literature about the relationships among different SPS. It is asserted that SPS are concatenated with one another rather than being independent skills (Baird & Borich, 1987, as cited in Roth et al., 1993), in which two different SPS could be related to each other. Besides, Kaur (1972) points out that when students are provided with the opportunities to make observations precisely, the improvement of their "Classifying" skills could be promoted. Kaur (1972) and Remmen et al. (2018) explain that "Observing" is the foundation for the development of "Classifying" skills. These may help to explain the positive effect of the development of "Observing" skills in facilitating "Classifying" skills development.

Provision of various examples

Students B3 and C3 expressed the provision of various examples during lesson activities has assisted them to develop their "Classifying" skills. They suggested that with the provision of common and approachable examples for teaching them how to do classification, they were able to compare the similarities and differences of the examples provided easily and construct corresponding keys to identify them. They believed that the provision of examples had facilitated their learning in this skill in the meantime.

"At that time, our teacher has provided us with a set of worksheets. On the worksheet, there are 8 Minions, and in fact they could be grouped into many types... For example, there is a Minion does not wear any clothes and the rest have wear clothes, and therefore, I can separate the one without any clothes from the others, and classify it as group 1. Then, for the remaining ones with similar appearance, we would precisely group them and observe what are their differences… [B]ecause the character is quite popular, which everyone knows it. Therefore, when we classify them, it is easy for us as we have a sense of kinship.""

(Student B3)

"My SPS that has improved is "Classifying". It is because recently, the Biology lessons have introduced the construction of keys and relevant knowledge. Thus, it makes my improvement in this aspect to be greater… For instance, during the lesson, our teacher had given us some photos of different fish species, and had taught us how to distinguish them based on their features, such that we can construct a key for identifying the fish species."

(Student C3)

This finding supports Wilke and Straits' (2005) claim. They believe that the provision of examples which involves personal associations enables students to develop their SPS and content knowledge concurrently. It is because these examples provide students with a sense of relevance that enables the knowledge being discussed becomes more valuable to them and also promotes their confidence in doing science. Meanwhile, to generate an appropriate response, students have to apply their SPS. This may in turn facilitates the development of their SPS. This may help to explain the facilitation of students' "Classifying" skill development with the presentation of various examples that are familiar and closely-related to them.

4.1.3 Designing Investigations

Students A2, B1 regarded this skill as their most developed SPS. For student A2, the reason for having this skill improved the most could be due to more emphasis on the different sub-categories listed in senior forms when compared to junior forms.

"It is because compared to my Junior Forms, although I have also conducted practicals, I may not have carefully tried to design an investigation or evaluate the results of the investigation, and also as I design investigation, I could learn how to ask questions and making hypothesis… these skills… Due to the shortened lesson time, we tend to finish the practical as our teacher introduce how to conduct the practical."

(Student A2)

This might be attributed to the social movement and COVID-19 pandemic in Hong Kong over the past 2 years. It is because during the social movement and pandemic, mixed mode of teaching was adopted (The Education Bureau, 2019; 2022a). Besides, some schools have shortened their lesson time in response to half-day schooling. Consequently, the lesson hours for covering all the contents in the curriculum is inadequate, in which teachers may tend to allocate less lesson hours to cover the skills for designing investigations as carrying out the whole process of scientific inquiry could be time-consuming for teachers (Kruea-In et al., 2018). Hence, the student might not experience the skills involved in designing investigations in her junior forms 2 years ago and her development in the skills might not be sufficient. However, since normal schooling has resumed since the end of 2022 (The Education Bureau, 2022b), her Biology teacher may have more lesson hours that could be allocated for covering "Designing

Investigations" skills in class, which in turn allows the student to have more exposure to the skills and her improvement could be the most compared to other skills.

In the meantime, for student B1, the reason for having this skill the most improved could be related to her increased awareness on the skills related to designing investigations especially, consideration of fair-testing by setting up control set-up, due to the routine of the teacher.

It is because during our lessons, after discussing the experiments, we will learn how the design the control set-up… In studying the growth of plant, I would be aware of they need the same things… After giving us the worksheet, he would ask us to discuss and he would invite us to suggest why we would have such answers (in determining experimental and control set-up)

(Student B1)

After each practical, the teacher would invite students to consider and discuss the control set-up involved. As the student was identifying the control set-up through discussions more as a routine, they might develop a high awareness on the importance of setting a control set-up and its identification when it comes to contexts related to experimental design. This might in turn result in the student believing this skill is improved the most.

From the responses of the participants, it is remarkable that the more emphasis on the different sub-categories of SPS listed in seniors forms and the enhanced awareness on the skills related to the SPS allows this SPS to be the most developed. The development of this SPS may be contributed to the provision of practice on the skill during their Biology lessons.

Provision of practice

Students A2 and B1 mentioned that different sub-categories of skills from "Designing Investigations" were integrated into their lessons, especially for "identifying variables". When they conducted practicals or encountered questions related to practicals, their teacher would usually invite them to identify the variables (i.e., independent variables, dependent variable and controlled variables) involved. After conducted more practicals or encountered similar practice more, they believed they had improvement in "identifying variables", a sub-category of "Designing Investigations" skills.

"It is because during our junior forms, we would also conduct practicals. However, these practicals mainly focus on the experimental result. Then, for now, from the beginning of the experiment, for instance, asking questions and identifying variables… because the questions in our exercises involve these skills…"

(Student A2)

"It is because, I have undergone more practice (on identifying variables), and also, independent variables are about the variable that you have to make changes in response to the experiment while dependent variable in some sense is equal to the result of the experiment… If I consider them carefully, I think I can better identify them now"

(Student A2)

"For example, after examinations or quizzes, and also normally, when we encounter questions related to identifying variables, our teacher would ask us to identify which one is the independent variable and which one is the dependent variable."

(Student B1)

This finding echoes with the finding of Rauf and colleagues (2013) about the emergence of students' skill in identifying variables before and during the practicals. Meanwhile, Roth and coworkers (1993) hold similar findings and has further suggested that students are able to identify different variables more precisely as they conduct more scientific investigations and become more familiar with the experimental context through relevant practice, in which the improvement could be attributed to the familiarity and similarity of the context. Therefore, this may explain why the students interviewed believed that as they conduct more practicals and undergo more practice, they found out that they have improvement in identifying variables.

Nevertheless, Student B1 reflected that although she could identify some of the variables in a context with slight changes of their previous practice, the identification of different variables was still hard when the problem is set in an entirely novel context which is not encountered before.

"[A]lthough our teacher has taught us how to identify variables over the past 2 years… However, I think… although I could understand what my teacher is talking about, after changing the question type, I may find it hard to identify different variables… It is because

although our teacher usually gives us some questions to teach us how to identify dependent and independent variables. However, sometimes, since the questions are different, we would forget how to identify. Although sometimes, when the questions are similar, we could remember a little bit."

(Student B1)

This finding is in line with the findings by Friedler et al. (1990), which have indicated that students tend to encounter difficulties in identifying the variables involved in new contexts. They have further suggested that this could be attributed to the involvement of more information processing and students' insufficient mastery in identifying different variables. This may have helped to explain the reason for students having difficulties in identifying different variables when new contexts (e.g., an experimental context from an unseen question) are presented. Yet, it is noteworthy that the student is still able to identify some of the variables in a similar context. This might be owing to the involvement of less information are required to be processed in similar contexts.

4.2 Least Developed SPS in Biology lessons

The least developed SPS in Biology lessons stated by students are "Classifying", "Designing investigations", "Conducting practicals", "Inferring" and "Communicating" skills. The possible reasons for these skills being the least developed would be discussed below.

4.2.1 Classifying

Student A4 affirmed that "Classifying" skill is his least developed SPS. This could be attributed to the teaching arrangement of the topic (i.e., Biodiversity") where "Classifying" skills is mainly introduced.

"It is because according to the teaching arrangements, "Classifying" is a relatively new topic, and the exercises and experiments that we have done before do not seem to require us to classify different things much… "Classifying" is comparatively new to me, and I personally do not have much chance to encounter it…. [C]ompared to other SPS, like "Observing" and "Conducting practicals", perhaps these are covered 1 year earlier, in which you have already practiced them for a year. However, for this new skill, perhaps you may encounter it just now…

(Student A4)

Rauf and coworkers (2013) have found out that "Classifying" is less inculcated during lessons in which teachers tend not to implement activities involving "Classifying" in their lessons, except for the topic about the identification and classification of different animals. Different from other SPS (e.g., "Observing", "Conducting Practicals"), this skill is mostly introduced in the topic "Biodiversity" covered in the later parts of the curriculum. Thus, he might not have

much encounter with this SPS, and in turn might not have sufficient development in this skill when compared to other skills. Consequently, he may regard this SPS as the least developed SPS in Biology lessons.

4.2.2 Designing Investigations

Student C1 argued the skill is the least developed SPS. This could be due to her problem in defining different terminologies in "Designing Investigations" skills. The problem might be attributed to teachers' unclear explanation of terms during lessons.

"Because I think the wordings are quite similar. I mean for example, hypothesis and predictions, their wordings are quite similar. And sometimes I find it hard to distinguish which one refers to which… [A]ctually in ZOOM, we cannot conduct experiments, then it would be quite confused for me in this part."

(Student C1)

The role of teacher in explaining different terminologies clearly is important to students' understanding of their meanings. For instance, Lawson (2009) suggests students tend to feel perplexed in differentiating "hypothesis" from "prediction" as majority of science teachers fail to explain the differences among the terms that both involve the meaning of prediction. Thus, since her Junior Science and Biology teachers may not explain the terms clearly in class, for instance, because of insufficient lesson time and practical activities conducted during hybrid mode of learning, the student might perceive she has not understood the definitions of the terms

involved in “Designing Investigations” well in both Junior Science and Biology lessons, and in turn may believe the skill is the least developed.

4.2.3 Conducting Practicals

Student B3 expressed the skill is his least developed SPS. This could be due to his lack of autonomy in choosing the topic and apparatus to be used in his practicals. This problem might be related to the provision of designated practical topics and apparatuses in his practicals by his teachers.

“If all apparatuses are provided, you would lack the skill for “choosing apparatus”. I mean apart from providing you with the standard apparatus, it is also possible to allow us to discover whether the apparatuses which are not provided could replace the standard apparatuses to achieve the same result…If not all the apparatuses are provided, then there may not have improvements. It is because for me, I still haven’t mastered this skill well as it is seldomly discussed in lessons”

(Student B3)

“Apart from having no chance for us to choose the apparatus on our own, we cannot choose the topic for conducting practicals… Usually the practicals conducted are usually limited to the ones on the textbook. For instance, the textbook has introduced photosynthesis, and we only conduct practicals on photosynthesis… and we do not have the chance to choose what practicals to do…”

(Student B3)

Students’ autonomy in learning is important to their perceptions towards their competence in learning. For example, the study conducted by Hofferber and colleagues (2016) have found out

that as students perceive themselves having a low autonomy in learning, their sense of competence in learning would be lower than students who have more autonomy in learning. Since the textbook had already stated the topic of practicals to be conducted and apparatuses required while his teachers had already prepared all the apparatuses to be used in the practicals, he might have found himself lack autonomy to choose apparatus during his practicals, and in turn had resulted in him believing he has low competence in this SPS, and regarded it as the least developed SPS.

4.2.4 Inferring

Student B1 mentioned this skill is the SPS that is her least developed SPS. This could be related to her lack of confidence in learning this skill which requires her to express her ideas and explanation in words.

"I don't trust myself (in constructing explanations) ... I don't know whether writing or expressing like this is correct or not… for "using multiple representations to present information and ideas" ... I don't know how to express what I could think of in my mind…"

(Student B1)

Students' confidence in learning is determining to their learning outcomes. For instance, the study of Telbis and coworkers (2014) has revealed that students' who have high confidence in learning would achieve a better performance in learning, and vice versa. Meanwhile, the research conducted by Everingham and colleagues (2017) has further added that students'

confidence in learning would affect students' satisfaction, retention and achievement in learning. These findings have implied that having low confidence in learning may adversely affect students' learning performance and satisfaction. In this case, since Student B1 lacks confidence in learning the skill, she may perform unsatisfactorily in the tasks related to the skill. In the meantime, she might have a low sense of achievement in learning the skill, which in turn may result in her believing this SPS is the least developed.

4.2.5 Communicating

Students A2 and C3 acknowledged this SPS is the least developed SPS for them. This could be related to inadequate opportunity provided for them to apply the skill, in which they rarely had the chance to draw the representations (e.g., graphs and diagrams) to present information.

"It is because…I did not have much exposure to this term much, and I haven't tried to use multiple representations to present information and ideas…"

(Student A2)

"Because, usually, I tend to use (write down) the results of the experiment (directly), but rarely use graphs and diagrams to help me present the result…In my impression, there are no laboratory reports (that requires using different representations to present information) written. There are only laboratory worksheets provided, which requires us to suggest the conclusions and identifying variables."

(Student B3)

Inayah and coworkers (2020) claim that students tend to have low "Communicating" skills because they are not familiar with the use of different representations (e.g., pictures, graphs and

tables) to present information during their learning progress, which may imply students' minimal development of their "Communicating" skills could be associated with their low familiarity to use different representations to present ideas. Since they had inadequate exposure to the application of different representations in class as they rarely have the chance to make use of these representations to present ideas, they were not accustomed to the use of different representations for presenting their ideas. Hence, they may believe they had no or miserly development in "Communicating" skills, and eventually regard this SPS as the least developed.

Chapter 5 – Conclusion

5.1 Summary

It is found that students have different perceptions on their most and least developed SPS during their Biology lessons. Although some students had the same SPS chosen as their most or least developed SPS, they seem to share different reasons. Meanwhile, students have their SPS developed through various teaching and learning activities. Table 3 summarizes the most and least developed SPS highlighted by students and how students develop these SPS in their Biology lessons.

Table 3: The Most and Least developed SPS and their development in Biology lessons from students' perceptions

SPS	Most developed	Least developed	Reason(s) for being the most/least developed	Development of SPS
Observing	✓		➢ Higher frequency of exposure to the skill	➢ Provision of hands-on experience
Classifying	✓	✓	<u>Most developed</u> ➢ Interest in the topic related to the skill ➢ Level of difficulty for acquiring the skill	➢ Relationship between "Observing" and "Classifying" skills
			<u>Least developed</u> ➢ Teaching arrangement	➢ Provision of various examples
Designing Investigations	✓	✓	<u>Most developed</u> ➢ More emphasis on	➢ Provision of practice

			the different sub-categories of SPS listed in senior forms ➢ Increased awareness on the skills related to the SPS	
			<u>Least developed</u> ➢ Teachers' unclear explanation of terms during lessons	
Conducting Practicals		✓	➢ Provision of designated practical topics and apparatuses	
Inferring		✓	➢ Lack of confidence in learning the skill	
Communicating		✓	➢ Inadequate opportunity provided to apply the skill	

5.2 Implications of the study

The reasons for the SPS being the most developed and the activities highlighted by students in enabling their SPS development during Biology lessons may serve as a reference for teachers' design and selection of lesson activities in class for enhancing students' SPS development. For instance, teachers may consider using different approachable and daily-life related examples in teaching "Classification" skills as it enables students to develop confidence in learning the skill thanks to the sense of relevance provided through these examples.

Besides, the reasons for the SPS being the least developed suggested by the students could provide insights for teachers to reflect on their current instructional design and consider whether their students may encounter similar problems in learning SPS, such that they could adjust their current instructional design to better support students' SPS development in class.

5.3 Limitations of the study

This study is conducted based on a sample of 21 students. Thus, it is not suitable to make generalizations about students' perceptions on their SPS development during Biology lessons, which is one of the common limitations of a qualitative research (Marshall et al., 2006). Still, this may help throw light on this topic. Besides, although students are divided into different ability groups, students participating this study are students of a Band 3 CMI school, it may not fully represent the perceptions of students from schools of other bandings.

5.4 Suggestions for further studies

Based on the limitations and findings of the study, one of the potential research areas would be the differences in perceptions of students across variables, for instance, ability levels and school type. Since the current study involves a group of Biology students from a Band 3 public local secondary school only, similar studies could be conducted in schools of different bandings or schools under the Direct Subsidy Scheme. It is because students of different abilities may have

different levels of mastery in their SPS during Biology lessons. Besides, the resources available for supplementing students' SPS development during Biology lessons could be different among different schools, which in turn may influence students' level of SPS development in Biology lessons. Therefore, the results of such investigations may help promote teachers' competencies in designing learning activities that could cater for learners' characteristics with the resources available.

Another possible research area would be students' perceptions on the effect of COVID-19 pandemic in their SPS development during Biology lessons in Hong Kong. It has been reported by many literatures that students worldwide have suffered learning loss school closures under the anti-epidemic measures (United Nations Sustainable Development Group, 2020; Engzell et al., 2021) while teachers encountered various challenges in teaching science online (e.g., Wisanti et al., 2021; Macias et al., 2022). Similarly, based on students' responses, it seems class suspension and mixed mode of learning during the pandemic have influenced their development of SPS during Biology lessons. Hence, these investigations may be useful for educators and policy makers in Hong Kong to review on the effect of the pandemic on students' development of SPS and provide insights to devise plans and policies to better support students' SPS development in Biology lessons if similar situation takes place in the future.

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Appendix 1

Online questionnaire

A. Questionnaire 問卷

Introduction 簡介

Greetings! This is Chan Nok Yin from B.Ed. (SCI) of The Education University of Hong Kong. I am currently conducting a final year project to study the development of science process skills (SPS) in Biology lessons of Hong Kong secondary schools over the past 2 years from students' perceptions. Completion of the questionnaire takes around 5-10 minutes, and participants are required to write down their names for follow-up purpose. However, the answers provided will **NOT** affect the results in any school assessments. The data collected will be kept confidential and will only be used for research purposes. The questionnaires will be discarded once the inquiry is complete. Thank you.

你好！我是來自香港教育大學科學教育榮譽學士的學生陳諾賢。由於課程需要，正進行一項問卷調查，以了解學生在過去 2 年，學生的科學過程技能在中學生物課中的發展。填寫問卷約需 5-10 分鐘，並須請閣下填寫姓名，以作跟進之用，但閣下所提供的答案**絕不會**影響閣下在任何校內評核之成績。所提供的資料將作保密處理，並只作研究用途。問卷會在研究完成後立即銷毀。謝謝。

Part 1 - Personal Information 個人資料

1. Name 姓名

_____

2. Age Group 年齡階層

A.	F.5 中五	B.	F.6 中六

3. Gender 性別

A.	Male 男	B.	Female 女	C.	Others 其他 (Please specify 請註明：_____)

Part 2 – Development of Students' Science Process Skills 學生科學過程技能的發展

Based on the scale provided, please indicate the extent that you agree with the statements and choose the most appropriate option for each statement. (1: Strongly Disagree; 4: Strongly Agree)

請根據提供的比例，註明你同意這些陳述的程度，並為每項陳述選擇最合適的選項。（1：非常不同意；4：非常同意）

	Statement		Strongly disagree 非常不同意 1	Disagree 不同意 2	Agree 同意 3	Strongly Agree 非常同意 4
1.	I think my **"observing"** skill, which includes, **(A) stating characteristics,** **(B) measuring sensibly and accurately, and** **(C) recording data**, have improved/enhanced in Biology lessons over the past 2 years. 我認為在過去 2 年的生物課，我的「**觀察**」技能，包括： **(A) 說出特徵、** **(B) 明智和準確地量度，以及** **(C) 記錄數據** 有所提升。	**(A)**	1	2	3	4
		(B)	1	2	3	4
		(C)	1	2	3	4
2.	I think my **"classifying"** skill, which includes, **(A) comparing similarities and differences,** **(B) grouping and ordering,** **(C) constructing keys, and** **(D) stating relationships**,	**(A)**	1	2	3	4
		(B)	1	2	3	4

	have improved/enhanced in Biology lessons over the past 2 years. 我認為在過去 2 年的生物課，我的「**分類**」技能，包括： **(A) 比較相似與差異、** **(B) 分組與排序、** **(C) 製作檢索表，以及** **(D) 說明關係，** 有所提升。	**(C)**	1	2	3	4
		(D)	1	2	3	4
3.	I think my **"designing investigations"** skill, which includes, **(A) asking questions,** **(B) predicting results,** **(C) making hypotheses,** **(D) identifying variables and** **(E) suggesting operational procedures with consideration for fair testing**, have improved/enhanced in Biology lessons over the past 2 years. 我認為在過去 2 年的生物課，我的「**設計探究實驗**」技能，包括： **(A) 提出問題、** **(B) 預測結果、** **(C) 提出假說、**	**(A)**	1	2	3	4
		(B)	1	2	3	4
		(C)	1	2	3	4
		(D)	1	2	3	4
		(E)	1	2	3	4

	(D) 辨識變量，以及 **(E) 提出實驗可行的步驟時，會考慮公平測試的需要，** 有所提升。					
4.	I think my "**conducting practicals**" skill, which is, **hands-on practice, such as** **(A) choosing apparatus,** **(B) handling apparatus and** **(C) taking precautions**, have improved/enhanced in Biology lessons over the past 2 years. 我認為在過去 2 年的生物課，我的「**進行實驗**」技能，即**實驗操作，包括：** **(A) 選擇儀器、** **(B) 運用儀器和** **(C) 採取預防措施，** 有所提升。	**(A)**	1	2	3	4
		(B)	1	2	3	4
		(C)	1	2	3	4
5.	I think my **"inferring"** skill, which includes, **(A) analysing and interpreting data,** **(B) evaluating data,** **(C) estimating errors,** **(D) constructing explanations and** **(E) drawing conclusions**, have improved/enhanced in Biology lessons over the past 2 years.	**(A)**	1	2	3	4
		(B)	1	2	3	4

	我認為在過去 2 年的生物課，我的「**推論**」技能，包括： **(A) 分析和解釋數據、** **(B) 評鑑數據、** **(C) 估算誤差、** **(D) 提出解說，以及** **(E) 作出結論，** 有所提升。	**(C)**	1	2	3	4
		(D)				
		(E)				
6.	I think my **"communicating"** skill, which includes, **(A) using multiple representations to present information and ideas, and** **(B) putting forward logical scientific arguments,** have improved/enhanced in Biology lessons over the past 2 years. 我認為在過去 2 年的生物課，我的「**傳意**」技能，包括： **(A) 使用多種方法表達資料和意念，以及** **(B) 提出合乎邏輯的科學論據，** 有所提升。	**(A)**	1	2	3	4
		(B)	1	2	3	4

This is the end of the questionnaire. Thank you for your participation! 問卷到此結束。感謝你的參與！

Appendix 2
Focus group interview questions

B. Interview with Students 與學生訪談

1. What is the SPS that you think you have enhanced/improved **the most** in Biology lessons over the past 2 years? Why? Can you give examples to illustrate the reason?
在過去 2 年的生物課，你認為你的哪一種科學過程技能的提升是**最多的**？為甚麼？能舉例說明原因嗎？

2. What is the SPS that you think you have enhanced/improved **the least** in Biology lessons over the past 2 years? Why? Can you give examples to illustrate the reason?
在過去 2 年的生物課，你認為你的哪一種科學過程技能的提升是**最少的**？為甚麼？能舉例說明原因嗎？

3. Do you think your **"observing"** skill have enhanced/improved in Biology lessons over the past 2 years? How and why?
在過去 2 年的生物課，你認為你的「**觀察**」技能有提升嗎？如何和為甚麼？

4. Do you think your **"classifying"** skill have enhanced/improved in Biology lessons over the past 2 years? How and why?
在過去 2 年的生物課，你認為你的「**分類**」技能有提升嗎？如何和為甚麼？

5. Do you think your **"designing investigation"** skill have enhanced/improved in Biology lessons over the past 2 years? How and why?
在過去 2 年的生物課，你認為你的「**設計探究實驗**」技能有提升嗎？如何和為甚麼？

6. Do you think your **"conducting practicals"** skill have enhanced/improved in Biology lessons over the past 2 years? How and why?
在過去 2 年的生物課，你認為你的「**進行實驗**」技能有提升嗎？如何和為甚麼？

7. Do you think your **"inferring"** skill have enhanced/improved in Biology lessons over the past 2 years? How and why?
在過去 2 年的生物課，你認為你的「**推論**」技能有提升嗎？如何和為甚麼？

8. Do you think your **"communicating"** skill have enhanced/improved in Biology lessons over the past 2 years? How and why?
在過去 2 年的生物課，你認為你的「**傳意**」技能有提升嗎？如何和為甚麼？

-End of Interview Questions (Student) 訪問問題(學生)完-