國 立 交 通 大 學 教 育 研 究 所

碩 士 論 文

以學習者生成性繪圖為科學學習策略之探究

Learner-Generated Drawing as a Science Learning Strategy

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The past two years was the best journey I have ever had. It seems like my hardest time but at the same time the sweetest time in these 24 months in institute of Education. Here and now I survived.

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Nietzsche once said "What doesn't kill you makes you stronger." And yes, now I am strong enough to face the real world. It's all because all who once helped me to grow. I am the luckiest one in the world.

Learner-Generated Drawing as a Science Learning Strategy

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ABSTRACT

The present study examined the use of drawing as a generative learning strategy for college students in understanding science text. Four drawing treatment conditions were used to test the hypotheses about what kind of supports have to be accompanied with the drawing strategy (LGD) during the constructive learning process? Ninety-six non-biology major college students were recruited and asked to read paragraphs about the human circulatory system. In pure LGD group (group D, N=23) participants were asked to construct drawings after reading the text; whereas in group DI (N=22) participants drew and were provided with illustration feedback. Participants in group DIP (N=21) received not only illustration feedback but also prompting questions while those in Group DIPE (N=23) were taught thoroughly about how to select main ideas from the text for organizing and integrating by drawing and provide with illustration feedback and prompting questions. Dependent measures included post-factual knowledge test, post-mental model and post-transfer test. The results showed that the participants in the group DIPE constructed the most accurate drawings and also scored significantly higher in every posttest than the group DI did while other groups D and DIP performed in between. Treatment, motivation and pre-mental model were predictive to the accuracy of drawing during treatment. Several typical drawings in four groups were selected for further qualitative descriptions. Implications for effective use of drawing in reading science texts were discussed.

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Chap.1 Introduction

In this industrial society, educational issues have always been at the center topic of public attention. However, it is not the learning or knowledge construction per se but the highest educational degree as the core of the societal or parental concern. For many parents, degree/diploma is the most significant that their children can get from schooling. Their rationale is that if one wants a good job, good wealth, good spouse, good family - all elements of a “good life”, (s)he needs to pass high stack examinations and go to quality schools/universities as the first start. This is why most parents focus on the learning outcomes of their kids and why many teachers could not but react to this urge. For a long time in Taiwan education system, a great emphasis is placed on examination outcomes while the classroom teaching inevitably aims solely at the evaluation of competences and the competition to place students on the top in the high stack examinations. Among a classroom, only a small proportion of students can be the winner; unfortunately, most students have to take the cruel facts that they are the losers at daily base. Educators have observed and criticized that the test-oriented teaching goal has led the students to react passively, lost learning interest and do not fully engaged in learning.

The outcomes from TIMSS and PISA both show that Taiwanese students performed impressively in science but possessed low interest and inference ability compared with students from other countries that exceled (李哲迪, 2009; 林煥祥, 劉聖忠, 林素微, & 李暉, 2008; 張殷榮, 2001). This evidence could support my notion that our students do not learn for understand but for gaining higher score and keeping up steps with others. Though Confucius (孔子, B.C770-B.C476) has stressed that “obtaining knowledge is a personal pleasant moment” but for most Taiwan secondary school students it is no longer true. “As a man sows, so shall he reap” was the true meaning of education; it is gradually forgotten by parents, teachers and students. Teachings for all and everyone should gain deep comprehension are less worthy noticing in nowadays

I have also observed the same situation in my class experiences, and wondering if there is a solution to deepen students learning but not just memorizing. Coincidentally, I read about a journal paper advocating that drawing is a good method for science learning. Additionally, numerous outstanding scientists have famous for their use of drawing as the aid in constructing their thinking process and the prototypes of their profound scientific breakthroughs. For example, Leonardo da Vinci, Isaac Newton, Richard Phillips Feynman and even Albert Einstein all are famous in using drawing as a comprehension tool and note-taking method. Their precious notes were preserved as a treasure for all human being until today and offer us new perspective of how should we learn science (figure.1.1, figure 1.2, figure 1.3, and figure 1.4 as examples).Though drawing was viewed completely incompatible with science learning for Taiwan parents and teachers, drawing still has its importance in Science learning.

Figure 1.1
Da Vinci’s note

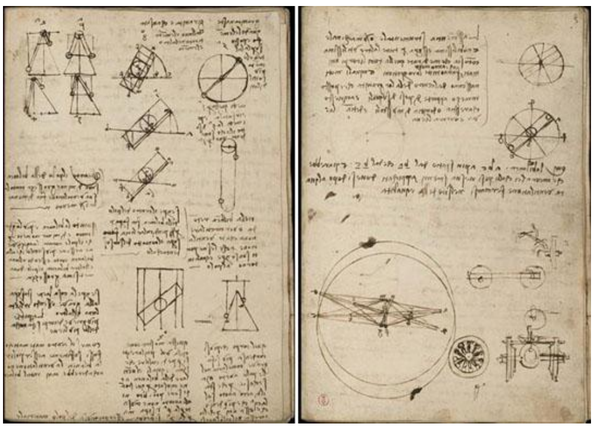


Figure 1.2
Newton’s note

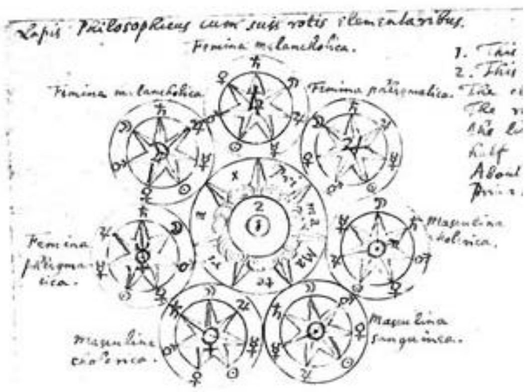


Figure 1.3
Feynman's note

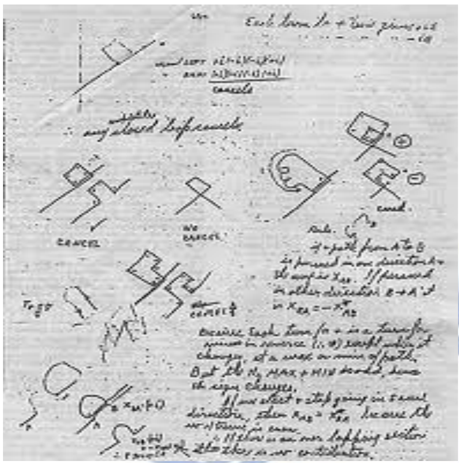
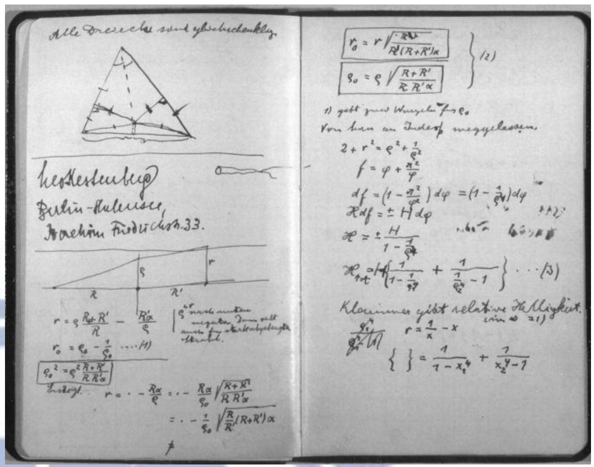


Figure 1.4
Einstein's note



I remember that in my early age, drawing is a very important and effective way when I attempted to solve problems and summarize concepts in textbooks. Personal experiences inspire me that drawing is a good tool to select critical information, clarify and organize concepts and integrate miscellaneous information into knowledge. It is also a tool to support my learning in science and math. Later on, in college years, my major was art and visual design. The professional training in visual design facilitates my ability to express critical ideas through visual elements. Above are the joint reasons that encourage me to study how to help students learn science through drawing. I appreciate that I have a chance to share the joy of learning by drawing and hopefully more students who are still struggling and suffering from learning could reduce their negative attitude towards science class.

Learning by drawing was studied flourishingly in 1970s; however because the research displayed mixed or even dispointed results (Lesgold, Levin, Shimron, & Guttmann, 1975; Snowman & Cunningham, 1975), it has grinded to a halt in the 80s. These early reseach fronts emphsized on drawing for the memory of narratives/stories and the research method/design was critized by van Meter and Garner (2005) as poor. However, some educators in recent years have gradually realize that drawing could be a concept organizer, argumentation simulator or mental experiment laboratory. From previous research (Ainsworth, Prain, & Tytler, 2011; Prain & Tytler, 2012), I found three reasons why students could draw to learn science: Drawing could enhance engagement, represent scientific ideas and indicate reasoning process. First of all, when drawing is used in class as a strategy to learn, students are forced to explore, to justify and to learn actively by drawing which frequently motivates them to participate more than in the conventional classrooms where students must sit patiently, silently and learn passively. Secondly, asking students to draw along reading science expository texts requires an active participation of selecting main elements, observing the phenomenon, explaining to them own and constructing the whole systematic mental model of the must-learn concepts. The drawing process makes the learners explain the content visually, concretely, and so clearly. Last but not the least, asking students to reason about science concepts by drawing could actively engage them in constructing science argumentation or mental experiments to produce science knowledge. Learners can generate their own illustrations to reason about the text and deepen their comprehension (Van Meter, Aleksic, Schwartz, & Garner, 2006) and at the same time, clarify their understanding of the topic. Students integrate the new information and the existing prior knowledge and then make new inferences. Also, drawing makes thinking visibly that it becomes a mental simulation platform to formulate inner experiments or even conduct imagery trials. These factors make drawing a useful way for scientific learning.

The current research agenda about "draw to learn" had been re-verified and the term was renamed as "Learner-generated drawing" (hereinafter LGD) (Mayer, Steinhoff, Bower, & Mars, 1995; Schwamborn, Mayer, Thillmann, Leopold, &

Leutner, 2010; Van Meter et al., 2006). Scientific domains have welcomed the use of LGD so far and are gradually establishing the crucial status of LGD in science learning (Ainsworth, Prain, & Tytler, 2011). The reason that science educators accept drawing as an instructional strategy partially because drawing is capable to reflect and facilitate the quality of mental model which is highly correlated with science concepts. Drawing involves the process of information negotiating, problem solving and also transfer. The study of beginners' drawing could deepen our understanding of the way learners study science (Ian, Miles, & Alister, 2003). What's more, after the drawing products been generated, previous researchers suggested to use some external supports to guide the learner's metacognitive process so that learners have a chance to reflect mistakes possibly made (Van Meter, 2001; Van Meter et al., 2006; Van Meter & Garner, 2005). Due to the aim of meaningful learning that I personally agree with, LGD is to facilitate higher-order learning outcomes, in my study higher-order assessments will be used to detect this type of learning outcomes.

At the end of first year in graduate study, with passion of drawing and ambition to be a good teacher, I attempted to do a final project on "whether drawing could be an effective learning strategy for all students" as the pilot study for my research. I chose junior high students as the participants, carefully selected a topic of human circulatory system which needs the aid of visualization, designed a theory-driven (selection-organization-integration, SOI principle proposed by Mayer, 1999) process and an elaborative text material. At that time I felt that my well-prepared drawing strategy would work perfectly for lovely junior high schoolers. Unfortunately, I was defeated by a whole class of non-motivated or anti-motivated students barely willing to draw. A small amount of students, who did follow my instruction to draw, showed very low level of drawing capacity. At the confusion crossroad, I repeatedly reflected what have gone wrong in my instructional attempt and re-read previous studies of drawing strategies. I came into some temporal conclusions that (1) due to the universal phenomenon; drawing is always regarded as an “art representation” but not a learning tool and was ignore in Taiwan education system. Many students are passive drawers who are not willing to construct the knowledge actively. (2) Some students have either no enough drawing skill or no experience to use drawing as science learning strategy; therefore, no improvement had shown though their drawing process. (3) My instructional approach needs substantial modification and reorganization to teach students to draw step by step. I decided to change my research topic as “to develop effective procedure and material based on drawing strategy for learning science topic which is highly related to visualization”.

Evidences have shown that LGD assists students to deepen comprehension of the presented text and built constructive mental model; however, this strategy is not always beneficial unless providing external supports. LGD could be used as a “pure” or “with support.” A pure LGD refers to that students receive a text purely directing students to draw; whereas the supported LGD refers to those students receive extensive aids (such as teacher provided feedback illustration or prompting questions) after drawing. Limited research has explored the issue about “Is an effective LGD necessary to be taught?” In most of the previous studies (Van Meter, 2001; Van Meter et al., 2006; Van Meter & Garner, 2005), the researchers merely reported that they asked students to draw a figure as it could appear in a science text book. It implied that most researchers believe that students could draw naturally and accurately without instruction. However, the pilot study revealed that drawing capability of the learner is an influential variable. Just like many learning strategies to be effective, students need explicit instruction (e.g., Selçuk, 2009).

According to the previous theory, the researcher dedicated to examine what are the additional aids necessary to accompany with this drawing strategy. In Biology, there are many topics relate to animals/human body structures and functions that emphasize visual components. Drawing diagram has an effect of actively transforming abstract-vague concepts into concrete-clear. There will four groups of (1) pure drawing (LGD) group (group D), (2) drawing with “Illustration feedback (Group DI),” (3) drawing with “illustration feedback and prompting questions,” (Group DIP) and (4) drawing with “illustration feedback, prompting questions and explicit instruction. (Group DIPE)”

This study used “learner-generative drawing” as the term of learning through drawing because I emphasize students’ active role in learning science. As the discussions above, the main purpose of this study is that “what are the additional supports necessary to accompany with LGD for the best learning outcome?”

Chap.2 Literature Review

2.1 Learner-Generative Drawing

1. Theory Base and Cognitive Process of Learner-Generated Drawing

Learner–Generated Drawing (LGD) is one of learning strategy which we expect to have benefits on the learners understanding. To investigate the theoretical foundation underlying LGD, we could introduce the operations of this strategy more specifically and clearly. Proved by previous research (Schwamborn et al., 2010; Van Meter, 2001; Van Meter et al., 2006; Van Meter & Garner, 2005), LGD is effective to enhance deeper comprehension on the must-learn text (Leutner, Leopold, & Sumfleth, 2009); however, why LGD is capable to deepen understanding has become a crucial role in this investigation.

Researchers suggest that LGD could bring out meaningful learning. Constructivists claim that "learning only occurs when learners construct their own knowledge and think reflectively when information presents" (Hsieh & Cifuentes, 2006; Lee, 1997). Wittrock (Wittrock, 1989, 1992) also asserted that a successful learning requires learners to generate the meaningful relationship among the parts of the text, between the text, knowledge and experience actively and dynamically. What's more, by conducting this process, learners could combine prior knowledge and new information; that is, they could reorganize, conceptualize and elaborate the relations, which increase the level of comprehension. Another statement was advocated by Mayer (1995) who also regards learning as a constructive process in which learners select and build cognitive connections among pieces of knowledge actively and integrate within their own past experience. In brief, meaningful learning emphasizes that learners integrate new and exist information actively; therefore, learners could have better achievement (Peper & Mayer, 1978, 1986).

Accordingly, three cognitive conditions for meaningful learning were proposed by Mayer (1995), which composited Wittrock's Generative Theory (1974), Pavio's Dual-coding Theory (1986) and Mayer's Theory (1993). Verbal and non-verbal modalities are working simultaneously. First, learners have to select the crucial elements from the presented text. Secondly, they organize the selected information to build up an internal model of the text. Last but not the least, they integrate the internal nonverbal representation of the text information and connect it with the verbal representation and with relevant prior knowledge. Worth noticing, the product of the combination could be viewed as the students' mental representation. Meaningful learning consists of building coherent metal model and can be measured by transfer performance (Mayer et al., 1995; Schwamborn et al., 2010).

Learner-generated drawing is the cognitive process which could be regarded as a metacognitive strategy (Schwamborn et al., 2010). By drawing, the students have to translate the verbal and nonverbal information into a picture which represents spatial relationship among functional elements. Therefore, learners have to engage in the presented text more than usual and to foster deeper comprehension. In line with above theories, the learning outcome of meaningful learning should not be measured by low level assessment - but have to be recorded by the higher level mental model (Leopold & Leutner, 2012).

Mental model is the representation of understanding structure in one's mind which is private and use to describe and explain the target phenomena (Johnson-Laird, 1980). Mental model could also be deemed to the inherent structural features that are associated with the contents that they presented by structural or functional analogy and allow learners to manipulate the model and read off relational information (Azevedo & Cromley, 2004; Fiore, Cuevas, & Oser, 2003; Gadgil, Nokes-Malach, & Chi, 2012; Hubber, 2006). By the definition, mental model development reflects students' condition of learning, the level of the information constructing and interacting status represents the mental model of the learner. Therefore, mental model provides a basis for drawing inferences and also enables the learners to generate new inferences for developing a deeper comprehension of the presented text (Butcher, 2006; Fisher & Harris, 1973; Ian et al., 2003; Van Meter, 2001).

I propose that LGD and the level of mental model are highly connected which LGD is a kind of mental focus strategy and assist learners to represent the features and relations structurally analogous to those reference contents. The higher level the mental model a student possesses the deeper comprehension one has. In this study, I examined the mental model level that showed in hand drawing to investigate how accurate is the learner's comprehension and what the gain through LGD.

2. Learner-Generated Drawing Strategy

Scientists use words and diagrams, graphs, photographs and other images to make discoveries and explain findings. However, in many science classes, drawing is mainly used in a passive manner: Teachers often ask learners to copy or interpret others' visualizations. It is rare that teachers encourage students to actively create their own visual forms of science concepts or to develop understanding. Is it beneficial that science teachers challenge students to draw more?

Learner-generated drawing (LGD) is defined as a learning strategy in which learners are given to read a text and to draw illustrations that correspond to the main elements and relations describe in each portion of the text (Schwamborn et al., 2010). LGD often is goal-directed, could be used to organize knowledge and when matched to the text, improves learning (Paris, Lipson, & Wixson, 1983). "Drawing" in LGD is intended to look-like or to accurately share a physical resemblance with the object(s) that the drawing depicts. “Learner-generated” means that the student is the primary causal agent in the construction and the appearance of the drawing. Student constructs drawings by free hand using only tools such as blank paper and pencil.

Unlike ordinary drawing or sketching, LGD is a learning strategy in which learners’ intention are more than just to portrait the outline of the topic and contents into visual form, also they have to illustrate functions, structures and relations between important visual elements (Van Meter, 2001). By means of LGD, a learner could systematically construct the contents; more importantly, this strategy is capable to strengthen the learners’ knowledge structure of text and create meaningful learning (Hsieh & Cifuentes, 2006; Van Meter et al., 2006). In this study, LGD refers to as a strategy which assists students to construct structural spatial relations of the presented concept, which makes LGD more than just an art representation.

Some researchers (Ainsworth et al., 2011; Schwamborn et al., 2010; Van Meter, 2001; Van Meter et al., 2006; Van Meter & Garner, 2005) claimed that by the process of representing concept visually, adding functions, constructing structure and linking relations between elements in generative drawing, learners are asked to engage, represent science main ideas and make critical reasoning and argumentations. To be specific, learners have to translate different information into verbal and visual forms and then demonstrate the spatial relation among the functional elements. Additionally, this cognitive process might require the students combining the new incoming information and the previous acquired information.

Although LGD received some attention in the 1970s, research interest dried up by the mid-1980s. It could be attributed to mixed findings and a body of research which is rather disappointing (Lesgold et al., 1975; Snowman & Cunningham, 1975). Nevertheless, with the role of students change by time, drawing to construct learning studies has restored. For example, Van Meter (2001) investigated whether drawing could improve 5th and 6th grade students' recall of complex scientific topic (central nervous system). They found drawing could improve students' engagement in self-monitoring of comprehension. This research team conducted a similar study in 2006 with improved research method (Van Meter et al., 2006). Again they found that drawing strategy could assist learning and promote the learner's metacognition. In line with Van Meter, Leopold & Leutner (2012) also showed that students learned better on chemistry concepts by drawing strategy. Related results could be seen in Hsieh's research about the benefits that student might get and the importance of this strategy (Hsieh & Cifuentes, 2006).

3. Accuracy

To assess quality of the LGD, this study intended to measure the accuracy of the drawing product produced during drawing treatment. Accuracy was defined as "the degree to which complete drawing resembles the presented object". Van Meter and Garner (2005) suggested to use accuracy of LGD as an important indicator of knowledge construction and till now only limited evidence has been reported (e.g., Schwamborn et al., 2010). In order to produce accurate drawing product, I expect the treatment main effect is critical while learners' prior knowledge and motivation should also play an important role. The **first hypothesis** is that pre-model, Questionnaire of Current Motivation (QCM) and the treatment were expected to influence the learner's accuracy.

2.2 External Support

According to the previous studies (Alesandrini, 1981; Van Meter, 2001; Van Meter et al., 2006; Van Meter & Garner, 2005), evidences have shown that LGD assists students to deepen their comprehension of the presented text and will built constructive mental model; however, this strategy is not always beneficial unless providing external supports. LGD could be used as a “pure” or “with support”. A pure LGD refers to that students receive a text purely directing students to draw; whereas the supported LGD refers to those students receive extensive aids (such as teacher provided illustration or prompting questions) after drawing. Previous experiments of LGD separated the external supports (feedback after drawing) into illustration only and illustrations with prompting questions.

Van meter (2001) and her series of studies have proved that learners who had received external supports engaged in more self-monitoring events and they tended to detect and correct more comprehension errors than those who received no external supports (Van Meter, 2001). Moreover, researchers (Alesandrini, 1981; Lesgold et al., 1975; Van Meter, 2001; Van Meter et al., 2006) suggest that there are three functions of external supports:

(1) To constrain the construction of drawing (direct attention to differentiate the relevant from the irrelevant); thus, learners would not be deviated from the text.

(2) To guide the students selecting and focusing on key elements and relations among the text contents.

(3) To prompt checking and correcting learner’s drawing (monitoring and regulation). By comparing the learner’s generative drawing and the prompting illustrations, students could detect their misunderstandings and make adequate correction, which increases the accuracy of students’ mental model.

Most of the studies (Butcher, 2006) claimed that external supports have benefits on students learning while using the drawing strategy. For example, serial studies of Lesgold et al (Lesgold et al., 1975) found that construction process plus handout of accurately organizing figures and background knowledge produced significant benefits. Alesandrini (Alesandrini, 1981, 1984) emphasized that learners required additional instructions and supports to attend to how each structure fits into the complete system. Only generative drawing is not enough for learners. When a student is able to compare the structural and functional resemblances between the external supports and ones' own drawing that would be a very important feedback about the complete schematic concepts, the alternative concepts that one may have acquired and the conflicts between the schematic concepts and the alternative concepts. This feedback if received by highly motivated students would help modify his/her mental model to show higher accurate scientific knowledge. Van Meter (Van Meter, 2001; Van Meter et al., 2006; Van Meter & Garner, 2005) has showed that in the group received external supports, students demonstrated higher accuracy and gain more knowledge. In this series of research, treatment were assigned into four levels, including (1) reading only (no draw), (2) draw (pure LGD), (3) IC (inspecting illustration handout after drawing and able to correct) and (4) PIC (inspecting illustration and prompting questions and able to correct). Fifth and sixth graders performed better and better in terms of deeper level of comprehension (free recall, drawing accuracy, self-monitoring and so on) along with the increasing levels of supports from IC to PIC.

Mayer (1984) suggests three types of supports, which is, supports having various cognitive functions. The study divided the supports into (1) selecting supports, (2) building internal connections supports and (3) building external connections supports. Selecting supports focus on the target information and serve to the learners certain aspects. By giving the selecting supports, the learner would construct the facts propositional representation of the information. The building internal supports foster the learners to organize the information into the structures. Building external connections supports are designed to help the reader build connections between the ideas in the text and an existing mental model, thus integrating these new ideas into leaner's existing priori mental model (Mayer, 1984; Resnick, 1982). These aids support the construction and extension of the mental model based on the propositional representations.

In many related studies (Schwamborn et al., 2010; Van Meter, 2001), researchers offered two levels of supported sources to ensure if the level of aiding could influence the outcome. In the same line, I differentiate external supports into three levels that would be compared with the pure drawing (LGD) group to examine what kind of components are required for LGD to be effective. This study claimed that external supports should be used with the most accurate visualization feedback that would the static features and dynamic functional purpose. There will be four treatment groups in this study.

(1) Pure drawing or LGD group (D).

(2) Drawing with "Illustration feedback" group (DI): After students' active drawing, the experimenter offers hand–drawing figure with keywords of organs and organization of the human circulatory system which assumed to be capable of providing embedded cognitive supports of "selecting main points" and "internal supports to present a visualization that integrates main concepts."

(3) Drawing with "illustration feedback and prompting question" group (DIP): After active drawing, students are given illustration embedded with directional-spatial cues and text-questions asking for allocating attention to main points (functional and directional information) in the illustration and meta-cognitive refection.

(4) Drawing with "illustration feedback, prompting questions and explicit instruction" group (DIPE): The experimenter explicitly presents all the cognitive supports described above and encourage students to actively practice drawing under teacher guidance"

However, “Prompting questions” are more like the combination of the selecting, internal and external aids. I expected that the group with “Prompting question” would perform better than “Illustration”. Accordingly, the ***second hypothesis*** is that when a learner is provided with external supports of illustration feedback, the effect would be mainly on the performance of post factual retention test but the effect on transfer test and post mental model would be limited. But when it comes to the ***third hypothesis***, that learner were given the prompting questions, (s)he would demonstrate more accurate and constructive drawing outcome and deeper comprehension than the one who does not obtain external support. For some students who are not good at drawing, have lower visualization capacity, or are more skillful in use of other strategy other than drawing who may need explicit instruction about why and how to do draw.

External supports in this study will be differentiated as “illustration feedback”, “prompting questions in addition to illustration” and also given “instruction” before LGD. According to the pilot study and the observation in class experience, I believe that students in Taiwan had less chance to conduct drawing activity and lack of interest. By instruction, students could not only be explicitly introduced to how to select, organize and integrate main points in to a visualization representation, but also given chances to practice. I expect this explicit instruction could build up confidence of the participants which may enhance students’ active engagement. That is, **the fourth hypothesis**, receiving instruction would benefit on the learners’ understanding revealed from all three post-tests. Additionally, through the instruction, learner could perform the best among other groups.

2.3 Characteristic of the posttest

In addition to the prompting feedback, the different formats of posttest might also be an influential factor on the result of LGD. In the learning psychology research, researchers use different posttests to investigate distinct leaning outcomes and displayed three widely-used characteristics, factual retention, transfer test and mental model. The question is, do the assessments really sensitive enough to examine the real knowledge acquisition? Or do the assessment methods fit the expected purpose?

According to the generative theory, LGD leads to the construction of higher-order mental model, which means learners actively integrate prior and existing knowledge, make inferences and apply newly learned to new situations. However, verbatim assessments could only measure factual retention but not to test the structural knowledge from the must-learned content. Only appropriate assessments will be expected to detect the acquisition of the constructed knowledge. Both transfer and mental model test could be regarded as suitable assessments to measure ability of inference and application; however, retention test is reveals to measure the factual knowledge acquisitions. Overall, Generative drawing should be tested by transfer test and mental model; however, retention tests are measuring the factual learning outcomes of LGD (Van Meter et al., 2006).

The mixed results about LGD functions in the previous studies might be partially caused by various posttests adopted by different researchers. In the study of Snowman and Cunningham (1975), they used multiple-choice that requires factual retention and so demonstrated little effect of LGD. By contrast, Dean and Kulhavey (1981) claimed that the map drawing activity had benefits for learners with free-recall posttest. Similarly, Alesnadrini (Alesandrini, 1981, 1984) used constructed format to test college students' comprehension and application to investigate if constructing drawing could deepen participants' understanding toward the cell battery. In Pepper and Mayer's (1986) study, students involved in generated activity (similar to the LGD) and the learners who drew and performed better on the transfer or problem-solving tests but not on the factual recall. Van Meter's studies (Van Meter, 2001; Van Meter et al., 2006; Van Meter & Garner, 2005) displayed the same results. Investigating whether LGD could improve science comprehension of elementary students, Van Meter placed participants to different conditions and gave different treatments; the effect of LGD only showed in constructed tests but not in lower one.

To ensure the effect of generative drawing, I expect characteristics of the posttest would play an important role in this study. I will try to identify various learning effects and will use three types of posttest including retention test, mental model test and transfer test to collect more aspects of the learning acquisition.

According to the previous research and hypothesis, this study proposed four research questions in below to examine the effect of LGD.

1. What prior factors (treatment, prior knowledge, pre-mental model and motivation) would influence learner's accuracy in various treatment groups?
2. Is there a significant main effect of illustration feedback on the performance of the posttest?
3. Is there a significant main effect of prompting questions on the performance of the posttests?
4. Is there a significant main effect of explicit instruction on the performance of the posttests?

Chap.3 Method

3.1 Participants

This study had recruited 96 college students as the participants of this study (53 undergraduates, 39 graduates and 4 Ph.D.). Participants were from schools of Kaohsiung and Hsinchu cities to increase the variety of student background (regional factor: north and south Taiwan). They are all non-science-related majors and expected to be cognitive mature enough to learn the biology alone but have not study biological issue for a while. Therefore, they have limited prior knowledge demonstrated in the pretest. There were 30 participants in group DIPI; 21 in group DIP; 22 in group DI; and 23 served in Group D. Description about group and treatments are in the following section.

3.2 Design

1. Independent Variable

There were four experimental groups given various levels of external supports with LGD. There were four different increasing levels of the external supports. Table 3.1 had demonstrated the descriptions of every each supports. 96 participants were randomly assigned to four groups listed in Table 3.2**.**

Table 3.1 Descriptions of supports

Pure LGD	No external support
Illustration feedback	Illustrations with labeled component keywords
Prompting questions	1. Illustrations with not only labeled component keywords but also directions and functions. 2. Five extra prompting questions about circulatory functions.
Explicit Instruction	1. A 30 minutes in-class course to teach students how to read and draw, including reading skills of selecting, organizing and integrating as well as mapping the main

	points in the text into a visualized form. 2. An exercise of LGD with teacher's feedback and guidance.

Table 3.2 Group assignment

Experiential group	Description
Group DIPE: Drawing +Illustrator feedback +Prompting questions +Explicit instruction;	Participants had an explicit instruction about the why and the how of "Draw for science understanding" for 30 minutes, concluding how to select that main idea, how to organize and how to integrate. While reading the text the participants were asked to use LGD to learn and they received an illustration of the main concept and also received 5 prompting questions after drawing for 20 minutes (see appendix H).
Group DIP: Drawing +Illustrator feedback +Prompting questions;	Participants used LGD when reading science text. They also received an illustration of the main concept and also received 5 prompting questions after drawing for 20 minutes.
Group DI: Drawing +Illustrator feedback;	The participants used LGD when reading science text but did not receive the prompting questions, only illustrations to support understanding.
Group D: Pure drawing	There will be neither instruction nor external support for the participants. They drew and read the text only.

2. Dependent Variable

This experiment will also assess three posttests matching as the Dependent Variables: retention test, transfer test and post mental model assessment. Different measurement of the posttest assessments would cause the outcome inconsistent.

(1) Retention Test

It is intended to assess the recognition of the must-learn content by multiple-choice items. The questions will contain factual knowledge questions in multiple choice format, assessing the recognition and the ability of retain the facts in instructional materials.(Appendix F)

(2) Transfer test

This assessment is consisted of open-ended questions to test the learner's ability to apply the newly learned contents to new situations and to make accurate inferences. (Appendix E)

(3) Drawing test (post mental model test)

To understand the quality of participant's metal model, this assessment intends to test if participants have the whole systematic conceptual knowledge of the text by means of drawing. A high accuracy and constructive drawing representation is consisted with structures, functions, connections between elements (relations) and system.

3.3 Material

1. Text

The science text will contain two topics. In the first section of instruction, an approximately 800-words text on "Cell Hypothesis" (in Chinese) will be used with three paragraphs to present three important concepts. The instructional Power-Point presentation includes 11 slides with ten pictures to reveal the importance and procedure of the drawing construction. The second topic in the instruction will be "Circulatory System". This text consisted approximately 1300 words, divided into six paragraphs about three main concepts. (Appendix A and Appendix B).

2. Booklets

Every participant will receive the text about Circulatory System and the same booklet contains all the questionnaires and tests (4 pages). Additionally, the booklet of DIPE group includes extra 5 pages of the drawing instructing “Draw for science understanding” outline with a sample text of Cell Theory for drawing practice.

3. Illustration feedback

The participants in group DIPE, DIP and DI had obtained the Illustration of Circulatory System (heart, vessel and circulatory system) after the drawing. The illustration had labeled the keyword; however, had not labeled the directions and functions, which represents the selecting and internal supports. (Appendix C)

4. Prompting question

The participants in DIPE and DIP obtained the Prompting Questions of Circulatory System (heart, vessel and circulatory system) after the drawing. This support had included 5 prompting questions to guide the learners checking their figures and words. What’s more, conditions with Prompting questions would also receive the directions and functions of the illustration. Overall, the Prompting Question support could regard as a propositional support (with functions and directions) and also a metacognitive support (which ask student to check their original figure), which is similar with selecting, internal and external supports. (Appendix D)

5. Explicit instruction

The participants in DIPE received a 30-min explicit instruction about “how to draw efficiently to learn” before drawing. Participants were all taught the skills for reading and drawing with selecting, organizing and integrating. They all have a chance to practice the topic “cell hypothesis” and teachers would give the feedback after the learners drawing.

3.4 Measure

1. Pretest

The Pretest includes demography questionnaire, prior knowledge test, pre-mental model evaluation, and a motivation questionnaire. .

(1) Demography questionnaire

It will collect the background information of the participants, such as id, school, place of residence, gender, educational background and the investigation of the whether learner had taken any the bio-related course.

(2) Pre-factual knowledge test

The purpose of this test is to examine participants' concepts about the terms and basic structures of Circulatory System. The correct answer in one blank gains 1 point and the highest score would be 14 (see Appendix E).

(3) Questionnaire on current motivation (QCM. Rhieinberget et al, 2001)

The motivation of learning science will be measured by Questionnaire of Current Motivation. This questionnaire is composed with 18 items of 7-point Likert scale.

(4) Pre-mental model test

This assessment is intended to test knowledge about structure of the circulation system and dynamic function conveyed in the text by means of drawing. The hand-drawing about the components, the whole system and the functions is regarded as the drawer’s mental model which reveals the level of the learner’s structure of knowledge. Learners were instructed to draw representational illustration (real life like) and every instructional procedure were all presented in appendix H. Please draw a diagram with the quality that it could be included into science textbook. Draw Heart. Draw Blood and Vessel. Draw the Circulatory System of human being". The mental model coding is based on the results of Butcher and Chi (Butcher, 2006; Gadgil et al., 2012) and researcher's pilot study which would be distinguished into eight levels (in Table 1). The higher represents the higher accuracy and more constructive. A highly accurate and constructive drawing (mental model) would consist of correct visual elements, connections between elements, structures, functions, and the dynamic relations to form the systems. The pre-mental model were score by the researcher, a high school biological teacher and a student assistant from department of biomedical imaging and radiological science with reliable interrater of ICC=.98. Participants with no drawing was regarded as no understanding of the target-text and gained 0 points in level zero. Level 7 is the most complete mental model of the learners and reflected the one had totally understand the circulatory system and could earn maximum7 points.

Table 3.3 Mental model coding

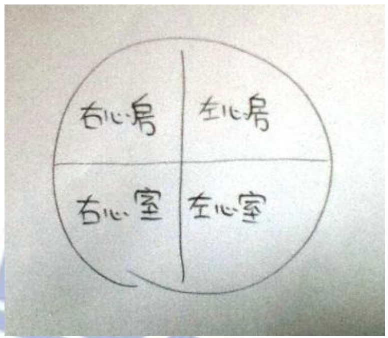
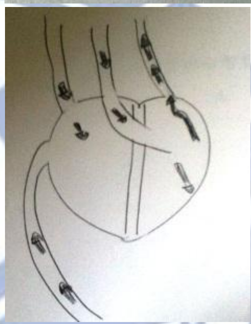
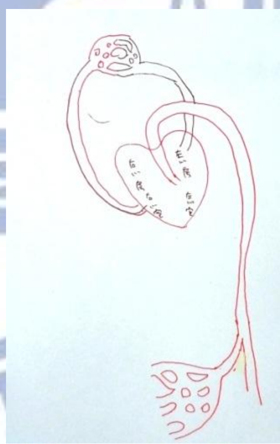
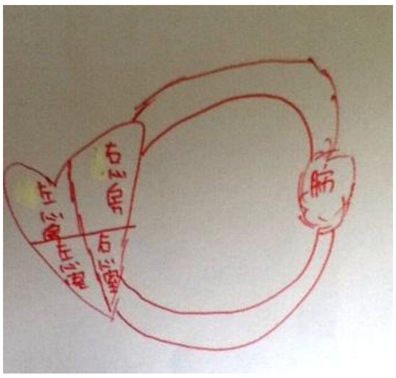
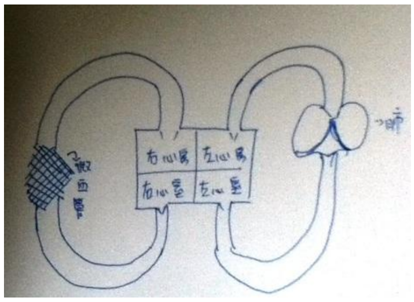
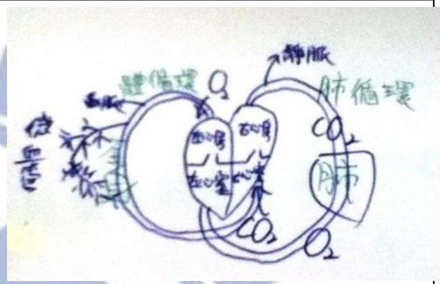
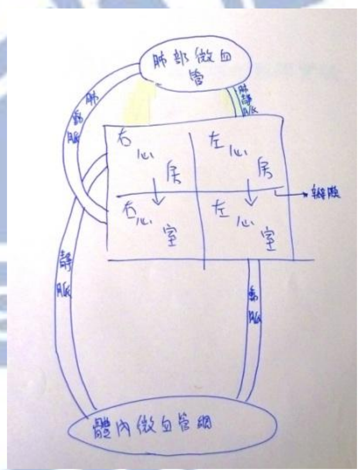
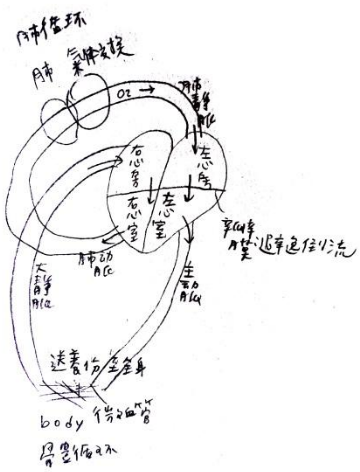
score	Level	Explanation	Illustration example
0	No loop	No understanding	No illustration
1	Ebb and flow/ Atrial and ventricular	Blood circulate or distinctions of the heart with Low-level purpose: oxygen transport. With partial structure and inaccurate links or flow directions.	 
2	Single loop	Single loop with a circulatory of body with lower purpose.	
3	Single loop with lungs or single loop with wrong description	Including the heart circulatory, the purpose of the transport and the lungs; however, lungs are not contain in the circulatory.	

Table 3.2 Mental model coding (cont.)

4	Double loop 1	Only contains whole circulatory (with heart and lungs) and without any descriptions.	
5	Double loop 2	Contains whole circulatory (with heart and lungs) but with incorrect or incomplete purpose and description.	
6	Double loop 3	Demonstrate a complete circulatory system with two circles and descriptions.	
7	Double loop 4	Demonstrate a complete circulatory system with two circles and exhaustive purpose , directions and description (which did not found in pilot study)	

2. Accuracy

Accuracy is the product of the treatment and reflected the quality that the learner conducting LGD. This will be coded to examine the level of understanding. Rating methods are totally the same as the pre-mental model test in the pretest. The accuracy were score by the three experts and with reliable interrater of ICC (intraclass correlation) =.97. Participants could earn maximum7 points.

3. Posttest

The posttest score reflected the quality of learning outcome. I distribute three posttests to measure the dependent variables: Retention test, Transfer test and Post-mental model assessment. The Posttest took place right after the treatment.

(1) Post- transfer Test

There will be 5 open-ended questions to test the learner's ability to transfer and apply the human circulation knowledge listed in the material to new situations. An example of the question states "John fell off and bruised, why didn't he infected by bacteria? Why did he stop bleeding? Please try to explain and try to write down the reasons" The accuracy were score by the three experts and with reliable interrater of ICC=.90. Three points reflects the best understanding for each item so that participants could earn maximum 15 points in post-transfer test. (Appendix F)

(2) Post-retention Test

This multiple-choice test is intended to assess memory of the factual knowledge or recognition of the important concepts in the materials. An example is"How many organs involve in the whole complete human circulatory system?

An example is" What is the main purpose of the lung circulatory? (A)Gas exchange (B) Deliver the nutrients (C) Against the pathogens (D) expel the blood (Item A is correct). Please see Appendix G.

(3) Post-mental model test

The drawing construction test was intended to assess student's comprehension and mental model by constructing illustrated representation. This drawing is intended to measure the learner's mental model after the treatment. Every rating method was completely the same as in pretest treatment. The accuracy were score by the three experts and with reliable interrater reliability (Intra-class correlation, ICC) = .98. Participants could earn 7 points maximally.

4. Statistic

This research is tended to assess whether LGD is a useful learning strategy. I emphasized the effect of the strategy and compare with the posttest between different experimental conditions. I will conduct the statistic data by ANOVA to test if the main effects are significant and if there are interaction effect. Additionally, to investigate the influence of the treatment, I also conducted multiple regression analysis to investigate the association between the variables.

3.5 Procedure

Participants were randomly assigned to one of four conditions. Each learner was seated in individual seat. The participants from DIPE group were extra taught a lesson called "draw for science understanding" to effective use the Learner-Generative Drawing strategy for 30 minutes before the treatment. Next, the learners were given the demography questionnaire and the prior knowledge pre-test, pre-mental model test and QCM (15 minute). After completing the pretest, students would receive the text and booklets for conducting LGD task. Group DIPE, DIP and DI were given appropriate supports after 20minutes and were able to revise their drawing by compare with the external supports. The Drawing group could have completely 30 minutes to draw. After the treatment, the posttest took place immediately; every participant could have 35 minutes to finish their posttest.(Appendix H)

Table 3.4 Procedure of the experiment

1. Grouping	Randomly assign 96 participants into four conditions.
2. Instruction	♦ DIPE conditions would receive an instruction of "Draw for science understanding" about the drawing skills and "Cell Hypothesis".
3. Pretest	♦ Demography questionnaire ♦ Pre-factual knowledge test ♦ Pre-mental model test Questionnaire on current motivation
4. Treatment	♦ DIPE ♦ DIP ♦ DI ♦ D
5. Posttest	♦ Post-retention test ♦ Post-transfer test ♦ Post-mental model test

Chapter.4 Result

4.1 Tests of prior group differences

Before analyzing the main effect of the treatment, this study tested group differences of participants' backgrounds, prior knowledge and motivation. The examination on group differences of gender was tested by χ^2 analysis and the result showed that there was no significance among four groups (χ^2=1.50, p=.22). Age difference was not found significance (F= (3, 92) =.49, p=.69, partial η^2=.16) when testing by the analysis of variance (ANOVA).

Additionally, prior knowledge (pretest factual knowledge) (F= (3, 92) =.23, p=.87, partial η^2=.008),pre-mental-model score (F= (3, 92) =.78, p=.51, partial η^2=.025), and score of the Questionnaire of Current Motivation (QCM) (F= (3, 92) =2.49, p=.07, partial η^2=.077) were all insignificant between groups. The descriptive statistics of pretest factual knowledge, pre-mental-model and motivation is demonstrated in Table 4.1.

Overall, the results indicate similarity among groups in their gender and age compositions, prior knowledge, and motivation.

4.2 Treatment effects

To examine the hypotheses of this study, an analysis of variance (ANOVA) was used to test the main effect on accuracy, retention, transfer and post mental model. Table 4.2 summarizes the descriptive statistics of the post-tests and post mental model score among four groups. Accuracy is rated by the drawing products when the participants were receiving treatment, it did not showed a significant difference between grops, F = (3, 92) = 1.64, *p* = .18, partial η^2=.06 (n.s.).

Table 4.1 Descriptive statistics of prior knowledge and motivation among four groups.

Experimental groups		Prior knowledge and motivation					
		Pre-factual knowledge		Pre-mental model		Motivation	
	n	M	SD	M	SD	M	SD
DIPE	30	8.60	2.77	.96	1.25	78.78	8.71
DIP	21	7.90	2.99	1.26	1.65	73.23	7.34
DI	22	7.91	3.43	.74	1.10	73.90	8.19
D	23	8.04	4.86	1.30	1.69	78.31	10.75

Note

DIPE group: Students were asked to draw a figure and provided with a feedback illustration, prompting questions and instruction.

DIP group: Students were asked to draw a figure and provided with a feedback illustration and prompting questions.

DI group: Students were asked to draw a figure and provided with a feedback illustration.

D group: Students were only asked to draw a figure. They did not receive any feedback or instruction.

Table 4.2 Descriptive statistics of retention test, transfer test and post mental model among four groups.

Experimental groups		Post-test achievement							
		Accuracy		Post-retention Test		Post-transfer Test		Post-mental model	
	n	M	SD	M	SD	M	SD	M	SD
DIPE	30	4.76	2.05	9.56	.81	9.15	3.80	5.41	1.77
DIP	21	4.60	2.17	9.52	.81	9.07	3.48	5.15	2.30
DI	22	3.42	2.50	8.63	1.32	6.68	3.64	3.57	2.53
D	23	3.76	1.97	9.34	.88	7.05	3.70	4.13	2.24

Note

DIPE group: Students were asked to draw a figure and provided with a feedback illustration, prompting questions and instruction.

DIP group: Students were asked to draw a figure and provided with a feedback illustration and prompting questions.

DI group: Students were asked to draw a figure and provided with a feedback illustration.

D group: Students were only asked to draw a figure. They did not receive any feedback or instruction.

Concerning the score of the retention posttest (multiple-choice items), the DI group achieved lower than the other three groups of DIPI, DIP and D, F = (3, 92) = 4.56, $p < .05$, partial η^2=.129 (Table 4.3). A Games-Howell post hoc analysis shows that only retention score of the Group DI was significantly worse than it in the Group DIPI; retention scores in the groups DIPI, DIP, DI did not show statistical differences.

Table 4.3 ANOVA summaries of group differences on retention, transfer and post mental model

	SS	*df*	MS	F	*p*	Partial η^2	*Post Hoc*
Post-retention							
Between	12.92	3	4.307	4.559	.005	.129	DIPI > DI
Within	86.91	92	.945		**		DIPI = DIP = D
Sum	99.83	95					
Post-transfer							
Between	122.70	3	40.90	3.023	.032	.090	
Within	1244.62	92	13.53		*		- -
Sum	1367.36	95					
Post-mental model							
Between	54.37	3	18.12	3.766	.013	.109	DIPI > DI
Within	442.72	92	4.81		*		DIPI = DIP = D
Sum	497.08	95					

* p < .05; ** p < .01

In addition, there shows a significant treatment main effect on transfer test score, F= (3, 92) = 3.02, $p < .05$, partial η^2=.09. The Scheffe post hoc analysis showed that there is no remarkable difference between groups DIPI and DIP (transfer M_{DIPI} = 9.15, transfer M_{DIP} group = 9.07, t = .07, p = 1).

Regarding participants' performance on post mental model, the result demonstrates a significant treatment main effect, F= (3, 92) =3.77, $p < .05$, partial

η^2=.109. A Game-Howell test shows that there is no significant difference between Groups DIPE and DIP again (post mental model M_{DIPI} = 5.41, M_{DIP} = 5.15, t = .19, p = .97). The LGD instruction seemed not effective to help DIPE students achieve higher than the DIP. However, M_{DIPI} is significantly higher than M_{DI} (t = 2.35, p = .05).

4.3 The comparative effects of prior knowledge, motivation and treatment on accuracy

Multiple regressions were used to explore the effect of pre-test score, pre mental model score, QCM and treatment on accuracy. The multicollinearity diagnosis (correlation, tolerance and VIF) did not show any exceptional value. The result of this analysis had summarized in table3. The overall model R^2=.26, reflected the strength of relationship between predictive variable and dependent variable was statistically significant, $F_{(4, 88)}$ = 7.59, $p < .001$. The model explained 26% variance of accuracy through prior knowledge, motivation and treatment.

Table 3 also shows the standardize estimate of regression coefficient and t value for each predictor as it entered the model. The effect reflected the standardized unit change in a predictor, controlling for other factors. Treatment, QCM and pre mental model had significantly impacted the results of accuracy; however, the pre-test did not. This result indicates that a participant with higher pre mental model and pre-motivation and receiving more supports during LGD process would perform better on accuracy. In conclusion, the supports (feedback illustration and prompting questions) seem to increase learner's drawing accuracy during treatment; however, motivation towards the task and the participants' integrative functional prior knowledge also play important roles in using this strategy for active learning.

Table.4.4 The predictive effects of treatment, motivation (QCM), prior knowledge on accuracy in a multiple regression analysis

Predictor Variable	B	B(SE)	β	*t*	*p*
Treatment	-.490	.177	-.255	-2.759	.007
QCM	.045	.023	.184	1.991	.050
Pre-mental model	.686	.161	.450	4.270	.001
Pre-factual knowledge test	.037	.065	-.060	-.569	.571
Model	$R^2 = .26$		$F\ (4, 88) = 7.59,\ p < .001$		

4.4 Qualitative analysis of the individual participant

As mentioned in the method chapter, there was a pilot test conducted in a class of junior high school students asking them to learn human circulatory system with LGD. Their drawing products were used to construct a coding system for the evaluation of drawing products in the current study with non-biology major post-secondary students. Though the age and education level of the pilot study participants were different from that of the participants in this study; however, the range (level 0 to 7) of drawing quality which demonstrates the conceptual understanding of human circulatory system remained the same. I also found that the best drawing product quality (level 7), which no one achieved in the pilot study, appeared in this study. Table 4.4 depicts selected typical drawing products for 7 levels (e.g., 0 = circulatory system with no loop, 1 = ebb and flow/Atrial and ventricular, 2 =single loop, 3 = single loop with lungs or single loop with wrong description, 4 = double loop-1, 5 = double loop-2, 6 = double loop-3, 7 = double loop-4) of coding in this study.

Figure 4.1: Mental model coding list

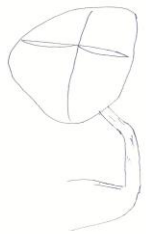
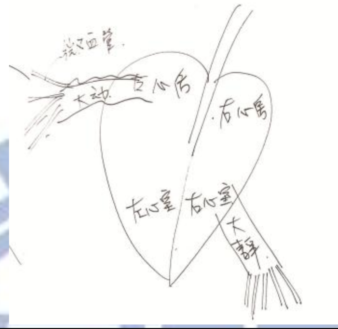
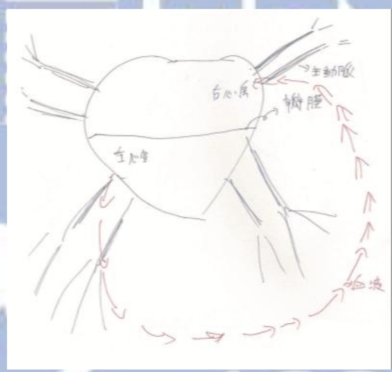
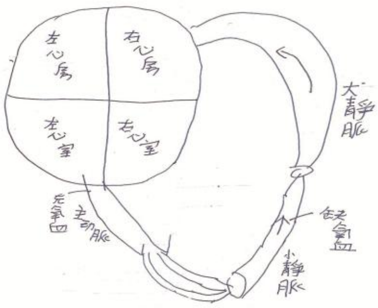
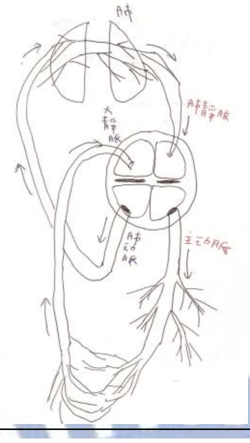
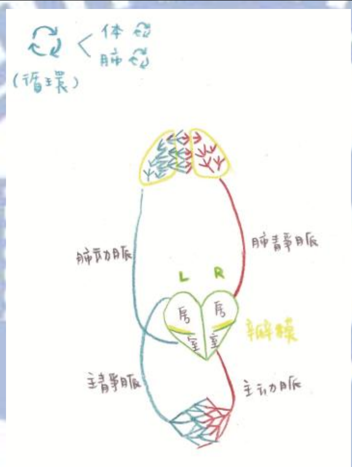
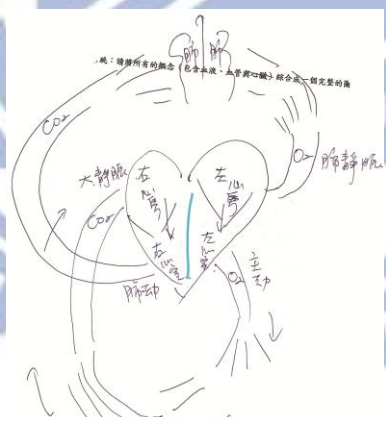
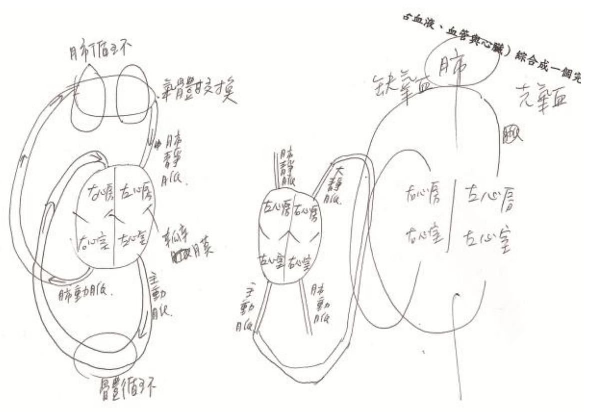
0: No loop	
1: Ebb and flow/ Atrial and ventricular	
2: Single loop	
3: Single loop with lungs or single loop with wrong description	 

Figure 4.1: Mental model coding list (cont.)

4: Double loop 1	
5: Double loop 2	
6: Double loop 3	
7: Double loop 4	

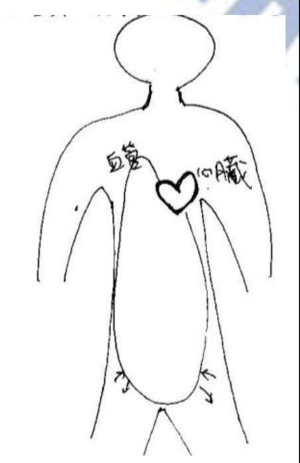
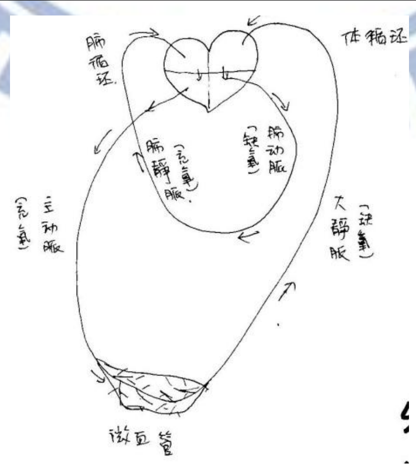
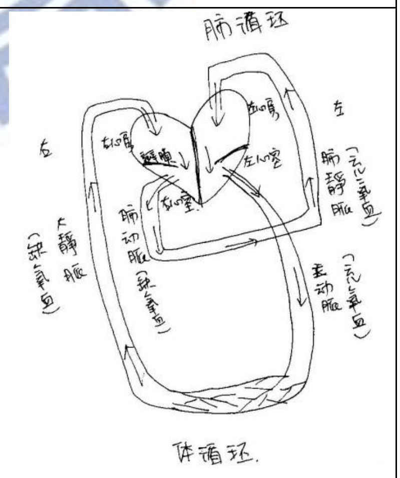
Eight cases selected from four treatment groups were listed in below for a further descriptive analysis. The observation of learners' serial drawings could be used as another approach to validate the results obtained from the statistical analyses.

Group DIPE

Drawing products of participant A: a gradual LGD benefit learner

The drawing products of participants A showed that before DIPI treatment (drawing, illustration feedback, prompting questions and LGD instruction), the pre mental model was in the low level of 1; while the accuracy score during treatment showed pretty good improvement to a level of 5. But, from the observation note the author jot down, the author found that this individual mainly took note when reading and might allocate less time in the integration of text and drawing. When it came to the posttest, the participants had enough time to integrate text and image materials, the post mental model revealed a highest level of conceptual understanding.

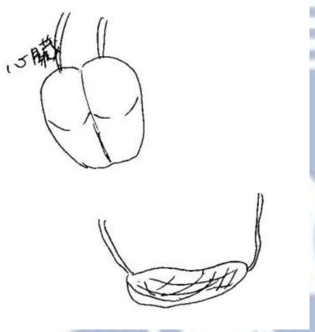
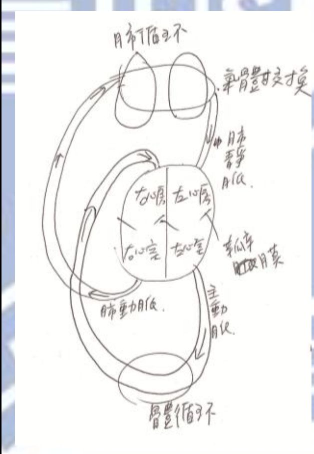
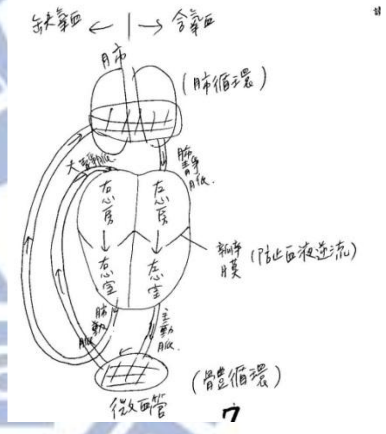
Figure 4.2: Drawing products of participant A

Pre-mental model: 1	Accuracy: 5	Post-mental model: 7
		

Drawing products of participant B: a dramatic LGD benefit learner

This is the learner with the most dramatic transition pattern across the study procedure and there were quite many participants showed this remarkable change in group DIPI. Participants B had barley no understanding in the beginning test (pre mental model) but during the treatment the accuracy score showed B participant's drawing achieved the best quality level of 7 and in the post-mental model the conceptual understanding was still the best. Even in the transfer test B gained 14 points.

Figure 4.3: Drawing products of participant B

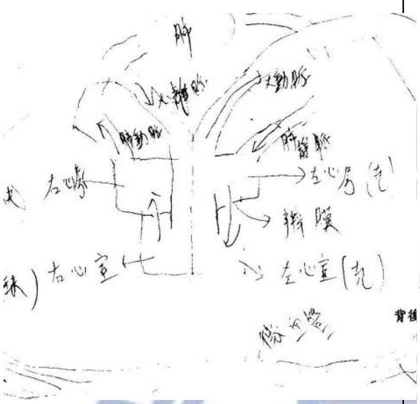
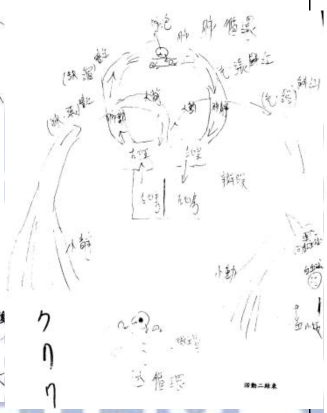
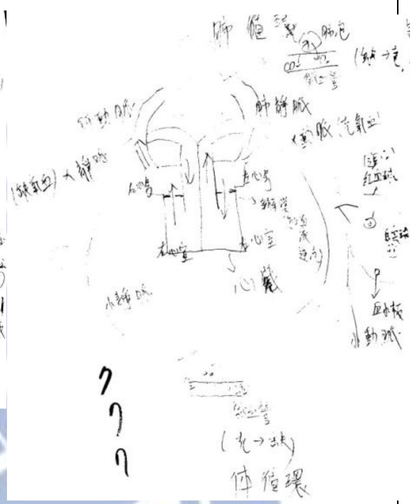
Pre-mental model: 0	Accuracy: 7	Post-mental model: 7
		

Group DIP

Drawing products of participant C: learner with high quality knowledge

In the group DIP (drawing, illustration feedback and prompting questions), the participant C demonstrated having a high quality of knowledge in pre-mental model and there were no room for the progress. The content of participant C's pre-mental model showed good understanding about component and organization of the circulatory system, only function of circulatory is missing. When it comes to the treatment accuracy, participant C had added the function and detailed description of the circulatory system, which make the treatment accuracy and post-mental model perfect.

Figure4. 4: Drawing products of participant C

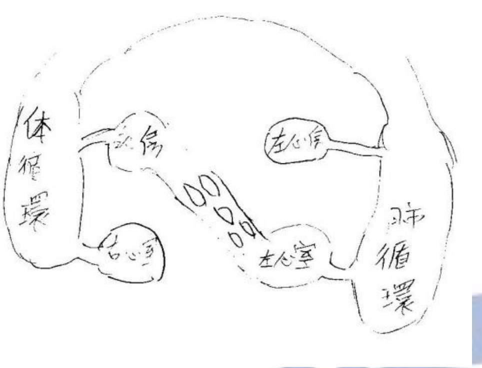
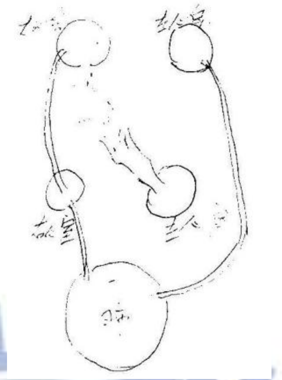
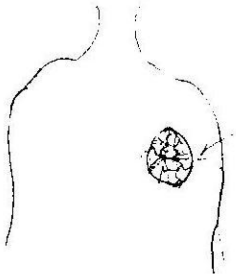
Pre-mental model: 6	Accuracy: 7	Post-mental model: 7
		

Group DI

Drawing products of participant D:could be give-up or poor understanding with poor motivation.

The participant D displayed poor understanding (level 0 to show no conceptual understanding of human circulatory system) all the way through pre-mental model, treatment to post-mental model. It demonstrated that this participant did not engaged in learning during the experiment.

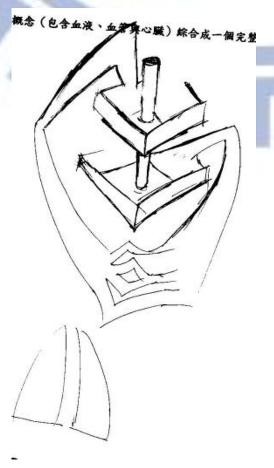
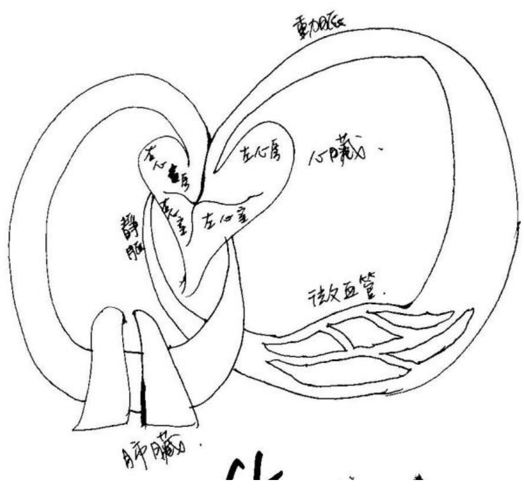
Figure 4.5: Drawing products of participant D

Pre-mental model: 0	Accuracy: 0	Post-mental model: 0
		

Drawing products of participant E: an un-interpretable learner

Participant E did demonstrate a level 2 understanding of human circulatory system. However, the drawing product during the treatment process dropped back to level 0. I infer that he was not willing to engage in leaning. At the end of the experiment, the participant E displayed a level 4 understanding in the post-mental model. The learning transition is hard to interpret.

Figure 4.6: Drawing products of participant E

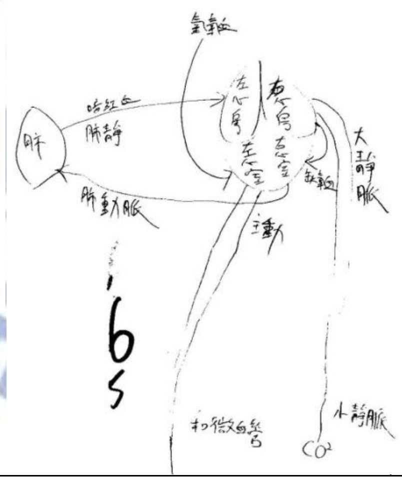
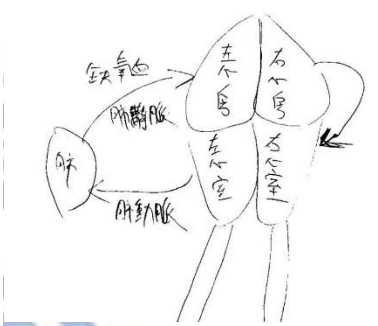
Pre-mental model: 2	Accuracy: 0	Post-mental model: 4
		

Group D

Drawing products of participant F: a learner once gets progress but regress eventually.

The drawing products of participant F show that he/she learned and integrated circulatory knowledge during the treatment (from level 2 in the first drawing to level 6 in the treatment); nevertheless, in the post-mental model the conceptual understanding dropped down to level 3. In group D, some participants displayed the same pattern as well. I speculate that due to the non-stop experiment tasks, the learner would probably exhaustive during the highly demanding activity and perhaps refuse for the further mental effort investment in the posttest.

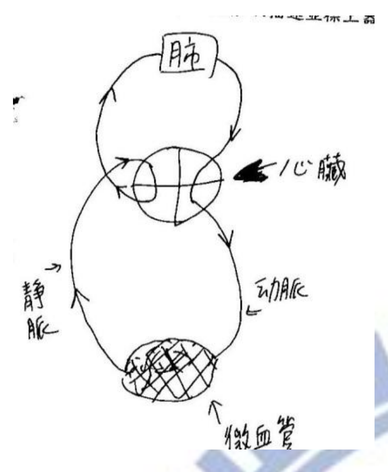
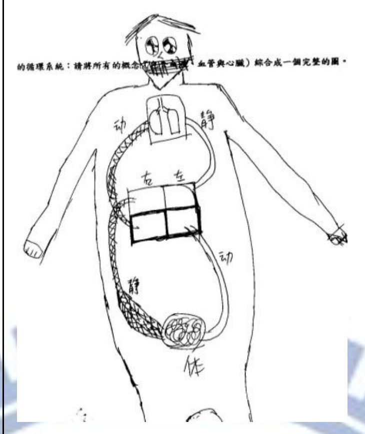
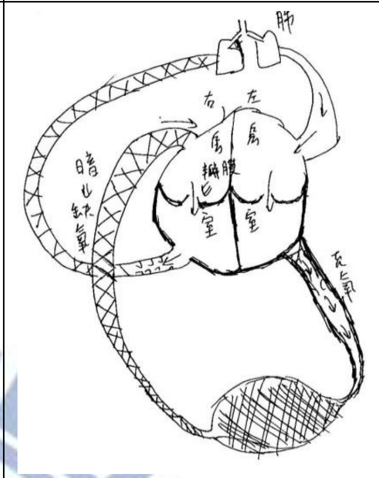
Figure 4.7: Drawing products of participant F

Pre-mental model: 2	Accuracy: 6	Post-mental model: 3
		

Drawing products of participant G: a no-improvement learner

There were no up and downs of participant G. Obviously this participant did not benefit from the strategy, which the learner might failed to grasp the main point of drawing. This pattern showed frequently in Group DI and Group D.

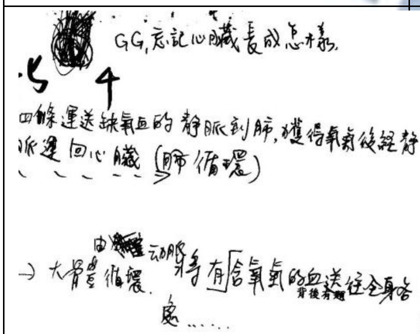
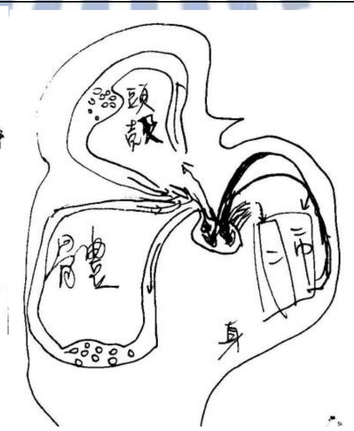
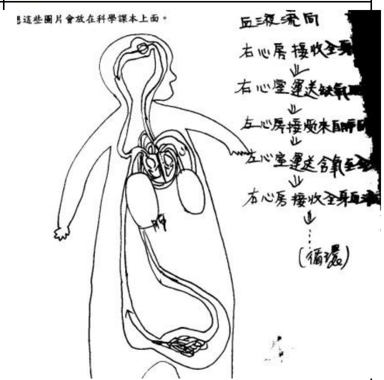
Figure 4.8: Drawing products of participant G

Pre-mental model: 4	Accuracy: 4	Post-mental model: 4
		

Drawing products of participant H: a verbal strategy learner

The participant G demonstrated a category of learners who might be not good at drawing or tended to be a text learner. In the observation note from the author, there seemed to be some leaners like to write text note and had shown little acquisition from drawing. However, the participants with low drawing ability seemed to be in the groups DI and D. Unfortunately, we are not able to investigate if this classification of learner could learn to draw through the DIPI instruction.

Figure 4.9: Drawing products of participant H

Pre-mental model: 4	Accuracy: 4	Post-mental model: 5
		

Chap.5 Conclusion and Discussion

5.1 Summary of the results

This study, based on previous research finding assumed a positive effect of Leaner-Generated Drawing strategy in science learning. The author also extended the research questions to test the relative effectiveness of different supporting conditions accompanying LGD. First of all, the result showed that explicit instruction (DIPE) is apparently more effective than receiving illustration with LGD (DI) in all outcome measures, from retention test, transfer test to post mental model, for non-science major college students. Conversely, receiving illustration along with LGD demonstrated the poorest understanding among four experimental groups. The observation of learners' serial drawings could be used as another approach to validate the results obtained from the statistical analyses. Researcher selected two typical leaners (participants A and B) benefited from the explicit instruction and their serial drawings at three time points either showed gradual or dramatic progress.

Second, the learning outcomes of receiving prompting questions (DIP) and pure LGD (D) were in between of (not significantly different from) the learning outcomes of either DIPE or DI. Without instruction, merely receiving prompting questions seemed to be a less effective external supports; however, if prompting questions could be given with an explicit strategy use instruction, the learning effects could be much better. The learners in these two conditions have shown various vague drawing patterns. Some of the learners reached a high quality level in pre mental model; some get regress eventually; some had no improvement; and some participants were more capable or willing to use verbal strategy (Participant C, F, G, and H).

Third, unexpectedly, pure LGD is not the least effective among four groups. The author suggests that illustration along with LGD might be used by learners as memory aid but not for the supports for selection, organization and integration. It is also possible that learners' motivation or pre mental model result in an interaction effect with the treatment so that learning outcomes of DI group was unexpectedly the worst. However, this study was not designed to explore the interaction effects of background factors (such as the interactions of pre mental model and motivation with treatment) but treated them as interferences that have been controlled. This study found two typical learners at the DI groups with poor pre mental models showed no improvement through three times of drawing who might simply give up learning or with low motivation and another learner showed un-interpretable learning pattern which could be also a low motivated participants.

Fourth, pre-mental model, motivation and the treatment explained about 1/4 percent variance of learner's accuracy. Pre-mental model is the strongest predictor, followed by the treatment and motivation. The task-specific schemata, brought into the experiment, are assumed to be the most powerful cognitive factor exerting effect on the accuracy; however, a short treatment designed by the author showed a second strong influence on the accuracy. Apparently, LGD is a learner-active strategy (Wittrock, 1989, 1992) in which the learner's engagement could enhance learning outcomes. There is no surprise to find that motivation showed the third powerful influence on accuracy.

Accordingly, Hypothesis 1 is supported that pre-mental model, treatment and motivation explains the learners' accuracy. The hypothesis 2 has been rejected that illustration feedback has no positively effect on the outcomes. What's more, the hypothesis 3 has also been rejected. The main effect of the prompting question showed an unclear result that the learning outcomes from group DIP showed no statistically difference between group DIPI and D. However, the non-significant result still casts some light to my exploration that group DIP was positioned in between the others. Hypothesis 4 was supported because receiving instruction benefits learners' understanding and the learners in DIPI group performed the best. Explicit instruction surly plays a crucial role to the effective of applying LGD.

The major outcome of this study are unanimous with the Generative Theory (Wittrock, 1989, 1992), which indicates participants would learn better when they actively engage in appropriate processing and receive supports while reading science text. Leaners that received prompting questions, illustration feedback, explicit instruction and used drawing strategy tended to gain significantly higher score on the post mental model, transfer test and even retention test.

Though the results do not completely support the original expectation, the outcomes still have some implications in applying Learner-Generated Drawing strategy. The results of this experiment suggest that that to reach the maximum efficiency of LGD teachers should arrange appropriate extra supports. The results are also consistent with the Generative Theory (Van Meter, 2001; Van Meter et al., 2006; Van Meter & Garner, 2005), which posits that learners are more likely to construct meaningful learning outcome if they engaged more in generative process. Similar patterns have been found in other experiment outcomes. Van Meter (2001) had claimed that drawing strategy could assist learning. Leopold and Leutner (2012) also showed that students learned better on chemistry concepts by drawing strategy. Hsieh's research (2006) suggests about the benefits that student might get and the importance of this strategy.

Non-major college students perhaps mature enough to adopt LGD strategy; yet, with explicit instruction, leaners reached the peak of meaningful learning. The contribution of this study is that, unlike the past investigations focused on the external supports, for a LGD to be most successful, it should be taught in explicit instruction with prompting questions.

5.2 Implications

This experiment offers a complete package of what is necessary when using LGD strategy. LGD emphasizes learners' active role to generate their own drawing product; however, the class experiments and observations by the author found that college students could not spontaneous use pure LGD or illustration/promoting questions along with LGD. This investigation points out that the explicit instruction is critical for LGD to be effective. If teachers plan to use LGD in junior high or high schools, the researchers suggest that the explicit instruction about how to draw would be very important.

What's more, many science topics in junior high or high school textbooks indeed need visualization for understanding; for example, past research has shown that topics in physics (e.g., nature of light, Newton mechanics), chemistry (e.g., bonding of substance), biology (e.g., neuron and brain function), astronomy, or even ecology. Therefore, LGD could be a long-term (such as a whole semester) learning strategy for use in science classes. If teachers are going to introduce LGD into science class, I suggest that an explicit instruction with appropriate package of supports is needed. Learners could generate more accurate visualization in the manner of meaningful learning.

In the observation from this study, some of school teachers ask students to use LGD nowadays. But it is a pity that a LGD with illustration would have it strict limitation. After an explicit instruction of effective LGD at the beginning of the semester, teachers could offer LGD activities, adding LGD into teaching materials, or use it as a formative assessment.

5.3 Limitations and Future predictions

There are several limitation need to discuss. First, there is no "traditional" control group (no drawing) in this study. Critics could argue that it is impossible to examine the effectiveness of LGD using my experimental design. However, since previous studies (Van Meter, 2001; Van Meter et al., 2006; Van Meter & Garner, 2005) in decades have all shown that LGD is good learning strategy, my research concern is basically on how to introduce LGD strategy to students. If one more control group is added into my design, the comparison of learning outcomes of the pure LGD group and the control group could be used to examine the main effect of LGD. Secondly, the participants in this study went through all experimental procedure continuously in one afternoon. Future work is suggested to investigate the longer-term effects of generative drawing. Third, the recruitment of the participants has its limitation. Future work is encouraged to invite students of various age groups to find out whether the LGD effects could be generalized to different students. Finally, this study used human circulatory system as the single topic of introducing and testing LGD effect. Future study could use topics of physics, chemistry or other science areas to test domain generalizability of LGD.

References:

Ainsworth, Prain, & Tytler. (2011). Drawing to Learn in Science. *Science*, *333*(6046), 1096-1097.

Alesandrini. (1981). Pictorial–verbal and analytic–holistic learning strategies in science learning. *Journal of Educational Psychology, 73*(3), 358.

Alesandrini. (1984). Pictures and adult learning. *Instructional Science*, *13*(1), 63-77.

Azevedo, & Cromley. (2004). Does training on self-regulated learning facilitate students' learning with hypermedia? *Journal of Educational Psychology, 96*(3), 523-535. doi: 10.1037/0022-0663.96.3.523

Butcher. (2006). Learning from text with diagrams: Promoting mental model development and inference generation. *Journal of Educational Psychology, 98*(1), 182-197. doi: 10.1037/0022-0663.98.1.182

Dean, & Kulhavy. (1981). Influence of spatial organization in prose learning. *Journal of Educational Psychology; Journal of Educational Psychology, 73*(1), 57.

Fiore, Cuevas, & Oser. (2003). A picture is worth a thousand connections: the facilitative effects of diagrams on mental model development and task performance. *Computers in Human Behavior, 19*(2), 185-199.

Fisher, & Harri. (1973). Effect of note taking and review on recall. *Journal of Educational Psychology, 65*(3), 321-325. doi: 10.1037/h0035640

Gadgil, Nokes-Malach, & Chi. (2012). Effectiveness of holistic mental model confrontation in driving conceptual change. *Learning and Instruction, 22*(1), 47-61.

Hsieh, & Cifuentes. (2006). Student-generated visualization as a study strategy for science concept learning. *Journal of educational technology and society, 9*(3), 137.

Hubber. (2006). Year 12 students' mental models of the nature of light. [Article]. *Research in Science Education, 36*(4), 419-439. doi: 10.1007/s11165-006-9013-x

Ian, Miles, & Alister. (2003). Promoting mental model building in astronomy education. *International Journal of Science Education, 25*(10), 1205-1225. doi: 10.1080/0950069022000017270a

Johnson-Laird. (1980). Mental models in cognitive science. *Cognitive science, 4*(1), 71-115.

Lee. (1997). Integrating concept mapping and metacognitive methods in a hypermedia environment for learning science. *ETD Collection for Purdue University*, AAI9808479.

Leopold, & Leutner. (2012). Science text comprehension: Drawing, main idea selection, and summarizing as learning strategies. *Learning and Instruction, 22*(1), 16-26. doi: 10.1016/j.learninstruc.2011.05.005

Lesgold, Levin, Shimron, & Guttmann. (1975). Pictures and young children's learning from oral prose. *Journal of Educational Psychology, 67*(5), 636.

Leutner, Leopold, & Sumfleth. (2009). Cognitive load and science text comprehension: Effects of drawing and mentally imagining text content. *Computers in Human Behavior, 25*(2), 284-289.

Mayer, Steinhoff, Bower, & Mars. (1995). A generative theory of textbook design: Using annotated illustrations to foster meaningful learning of science text. *Educational Technology Research and Development, 43*(1), 31-41.

Mayer, R. E. (1984). Aids to text comprehension. *Educational Psychologist*, 19, 30-42.

Mayer, R. E. (1993). Comprehension of Graphics in texts: An overview. *Learning and Instruction*, 3, 239-245.

Paris, Lipson, & Wixson. (1983). Becoming a strategic reader. *Contemporary Educational Psychology, 8*(3), 293-316.

Peper, & Mayer. (1978). Note taking as a generative activity. *Journal of Educational Psychology, 70*(4), 514.

Peper, & Mayer. (1986). Generative effects of note-taking during science lectures. *Journal of Educational Psychology, 78*(1), 34.

Prain, & Tytler. (2012). Learning through constructing representations in science: A framework of representational construction affordances.

Schwamborn, Mayer, Thillmann, Leopold, & Leutner. (2010). Drawing as a Generative Activity and Drawing as a Prognostic Activity. [Article]. *Journal of Educational Psychology, 102*(4), 872-879. doi: 10.1037/a0019640

Snowman, & Cunningham. (1975). A comparison of pictorial and written adjunct aids in learning from text. *Journal of Educational Psychology, 67*(2), 307.

Van Meter. (2001). Drawing construction as a strategy for learning from text. [Article]. *Journal of Educational Psychology, 93*(1), 129-140. doi: 10.1037//0022-0663.93.1.129

Van Meter, Aleksic, Schwartz, & Garner. (2006). Learner-generated drawing as a strategy for learning from content area text. *Contemporary Educational Psychology, 31*(2), 142-166. doi: 10.1016/j.cedpsych.2005.04.001

Van Meter, & Garner. (2005). The promise and practice of learner-generated drawing: Literature review and synthesis. *Educational Psychology Review, 17*(4), 285-325.

Wittrock. (1989). Generative processes of comprehension. *Educational Psychologist,* *24*(4), 345-376.

Wittrock. (1992). Generative learning processes of the brain. *Educational Psychologist, 27*(4), 531-541.

孔子. (B.C770-B.C476). 學而一. *論語, 學而一.*

李哲迪. (2009). 臺灣國中學生在 TIMSS 及 PISA 的科學學習成果表現及其啟示. *教育人力與專業發展, vol026_06_10*(學生學科能力品管機制), 16.

林煥祥, 劉聖忠, 林素微, & 李暉. (2008). 臺灣參加 PISA 2006 成果報告. *行政院國家科學委員會計畫成果報告 (報告編號: NSC 95-2522-S-026-002), 未出版.*

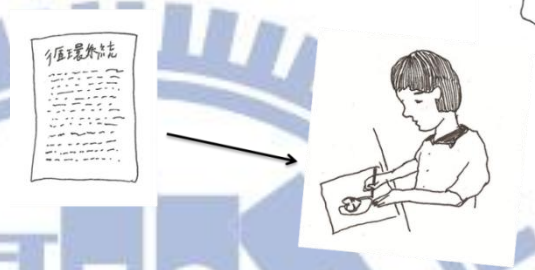
張殷榮. (2001). 我國國中學生在國際測驗調查中科學學習成就影響因素之探討. *科學教育*(244), 5-10.

Appendix

A. Sources of “Draw for science understanding”

「用畫畫、學科學」

該怎麼用畫畫來學科學？



該怎麼讀?

- 標題與關鍵字：重點在哪裡？
- 動詞：功能?方向?
- 關聯性：關鍵字和動詞的關聯在哪裡？
- 系統：不同關係間組成甚麼？

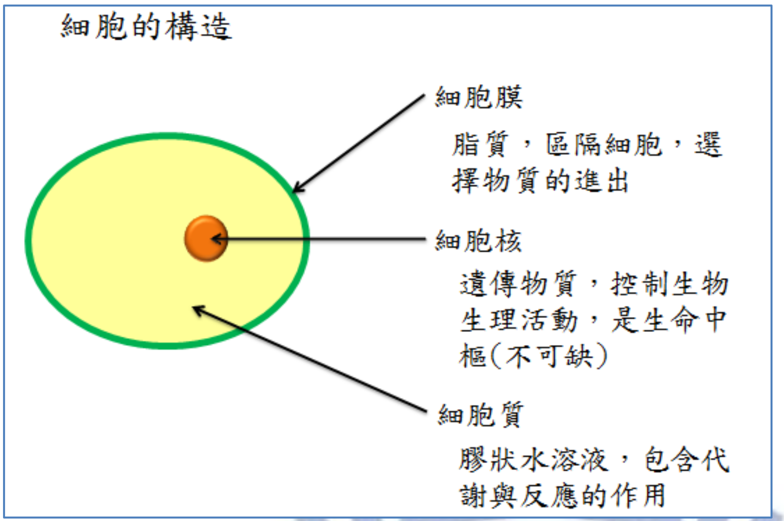
齒輪的轉動

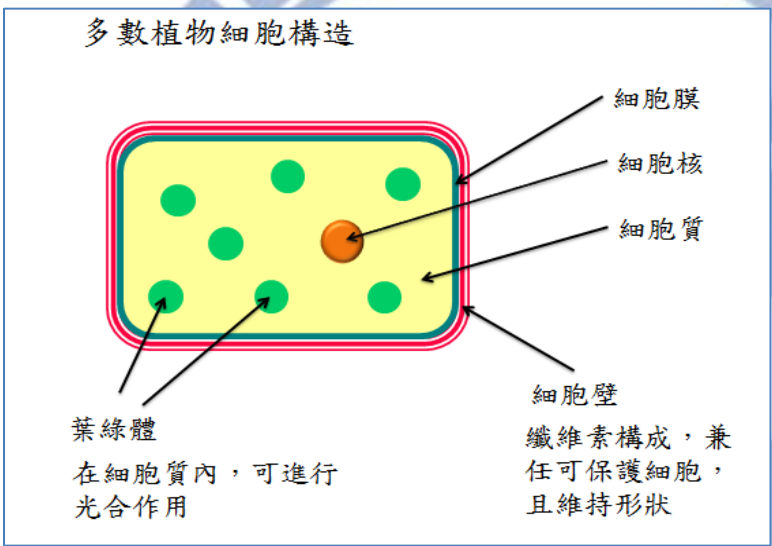
我們常會利用齒輪轉動的特性，使得生活更加便利，例如腳踏車的前進就是其中之一。腳踏車是利用踏板的踩動使大齒輪轉動，轉動的大齒輪帶動鍊條，使

該怎麼畫?

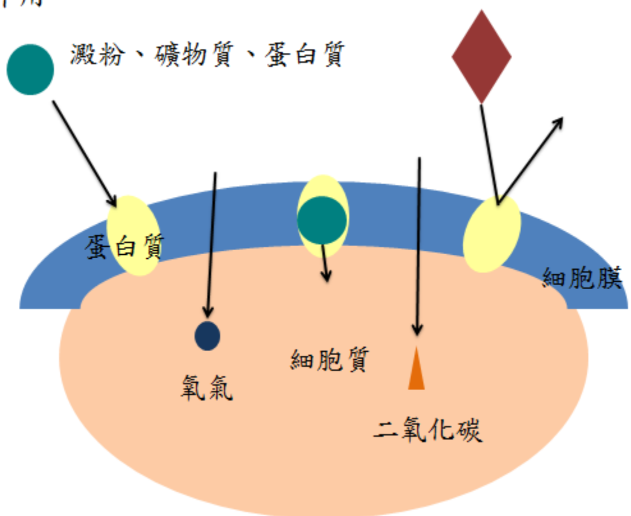
想像要畫的圖片會在自然課本裡面出現

- 標題
- 圖像與關鍵字
- 箭頭
- 補充說明


細胞的構造
細胞膜
脂質，區隔細胞，選擇物質的進出
細胞核
遺傳物質，控制生物生理活動，是生命中樞(不可缺)
細胞質
膠狀水溶液，包含代謝與反應的作用


多數植物細胞構造
細胞膜
細胞核
細胞質
細胞壁
纖維素構成，兼任可保護細胞，且維持形狀
葉綠體
在細胞質內，可進行光合作用

擴散作用


澱粉、礦物質、蛋白質
蛋白質
細胞膜
細胞質
氧氣
二氧化碳

B. Learning Text

心臟的分區：

心臟是血液循環的原動力，利用反覆收縮與舒張而使全身血液流動。人類的心臟位於胸腔中，約等同於自己的拳頭大小，由肌肉構成，內有四個腔室，上面為**左心房、右心房**，下面為**左心室、右心室**；在心臟下方的為心室，**心室**將血液推向動脈，**心房**則是接收血液的場所，右心房連接大靜脈，左心房則與肺靜脈連接，右心室連接肺動脈，左心室則連接主動脈。心房和心室、心室與動脈間有**瓣膜**，可以防止血液倒流。

心臟的肌肉會進行有規律的收縮和舒張，心房有較厚的肌肉能擠壓血液，收縮時，壓迫心臟內的血液流入動脈中；相反的，舒張時，靜脈內的血液變流回心臟中。心臟跳動時，當心室收縮心房與心室間的瓣膜關閉，血液衝擊瓣膜產生「噗」的聲音；心室舒張時，動脈中的血液則回流衝擊心室和動脈間的瓣膜，產生「通」的聲音，如此聽到的「噗──通」便是一次心搏的聲音。

血管與血液：

血管是血液在體內流動的通路，血管中，管壁比較厚而且富有彈性，稱為**動脈**。最粗的動脈和心室相連並分支，分支越分越細，佈滿全身。血液經由動脈輸送至身體各部，並且流速較快，動脈分支的末端是**微血管**，微血管管壁只有一層細胞組成，血液和組織間的物質在此發生交換。微血管所匯集的血液流入**靜脈**，靜脈的管壁比動脈薄，也比較缺乏彈性。小靜脈逐漸匯合成大靜脈，最粗的靜脈和心房相連，身體各部的血液，便經由靜脈流回心臟。

血液是時由血漿與血球組成，其中血球包含**紅血球、白血球**和**血小板**三種；紅血球含有血紅素使血呈現紅色，並能和氧氣結合，將氧氣運輸到全身以供給細胞利用。白血球略大，主管身體裡的防禦作用，當外來的病源侵入人體，白血球能將病原體吞噬、有些則能產生抗體，保護人體健康。血小板體積最小，當身體

受傷出血，血小板會幫助血液凝結，避免失血過多。血液則分成充氧血和缺氧血，當血液中氧氣較少，並帶有大量二氧化碳和廢物，呈現暗紅色，稱作**缺氧血**；當血液攜帶較多氧氣，則稱**充氧血**，呈現鮮紅色。

人體的循環（體循環與肺循環）：

人類的血液循環是由心臟、血管與血液組成，且分成**體循環**與**肺循環**；而在動脈與靜脈之間有網狀的微血管相聯繫。

體循環：

由當心臟收縮時，充滿氧氣的血液（充氧血）由**左心室**流入主動脈，並經過身體中許多重要的血管分支，越分越細，最小的分支與微血管相連，再將氧氣與養分進入周圍的細胞，接著細胞所產生的二氧化碳等廢物組織起來，擴散至微血管中。之後，載著廢物的血液（缺氧血）慢慢流入小靜脈，逐漸匯集至大靜脈，進入**右心房**。

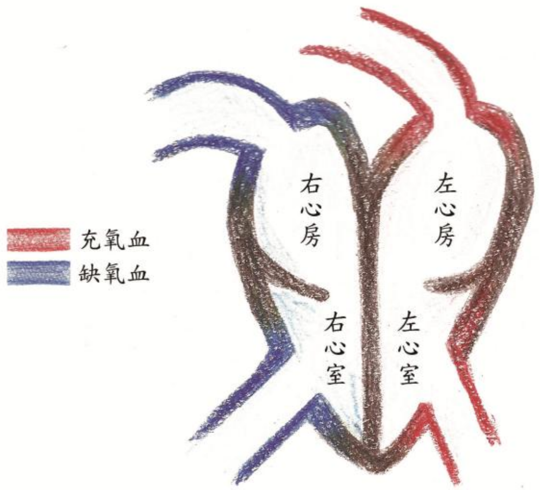
肺循環：

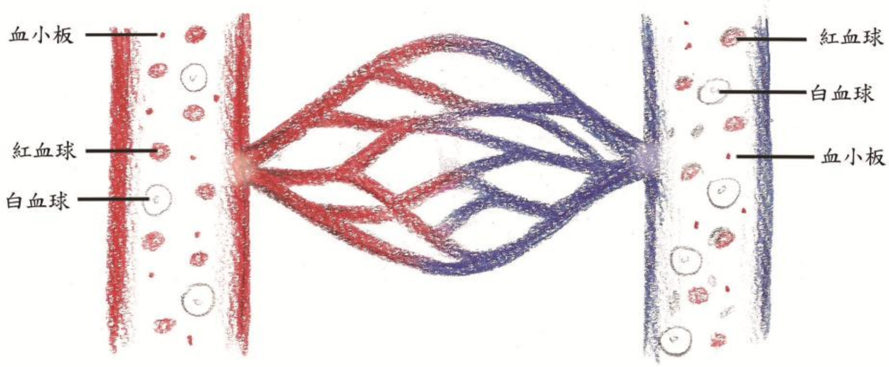
當身體各部位的血液流回右心房，所含的氧氣隨著循環逐漸減少，變成有大量的二氧化碳等廢物（缺氧血）；心臟收縮時，缺氧血由右心房進入**右心室**，且經動脈將這些暗紅色的血液壓送到肺部，血液在微血管與肺泡中進行氣體的交換，交換氣體後，血液含有較多的氧氣，所以呈現鮮紅（充氧血），這些血液經由肺靜脈流回左心房，再度開始體循環。

提示：體循環與肺循環並沒有先後的順序，而是兩個連結而不斷的循環；我們常認為在動脈裡的血流的是充氧血，而在靜脈裡的血是缺氧血。但**事實上**透過肺循環含有許多氧氣的才稱充氧血，氧氣含量低且二氧化碳含量高稱作缺氧血。因此，很特別的是，肺動脈裡的血稱作缺氧血，在肺靜脈流動的則是充氧血。

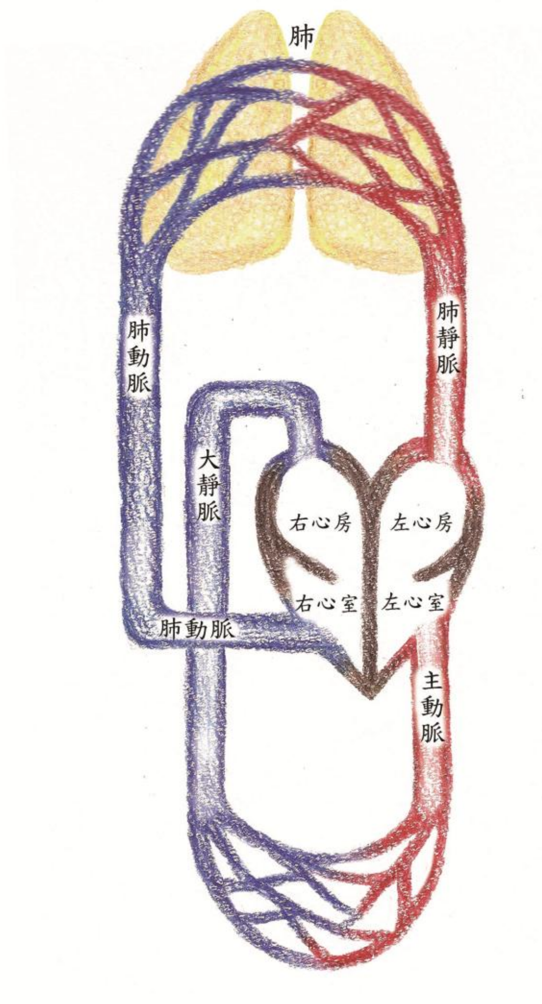
C. Illustration Feedback

心臟、血管與血液



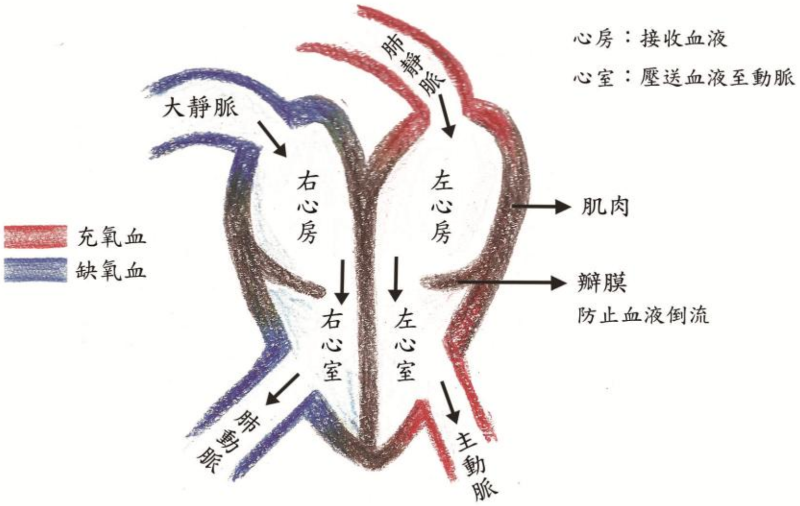


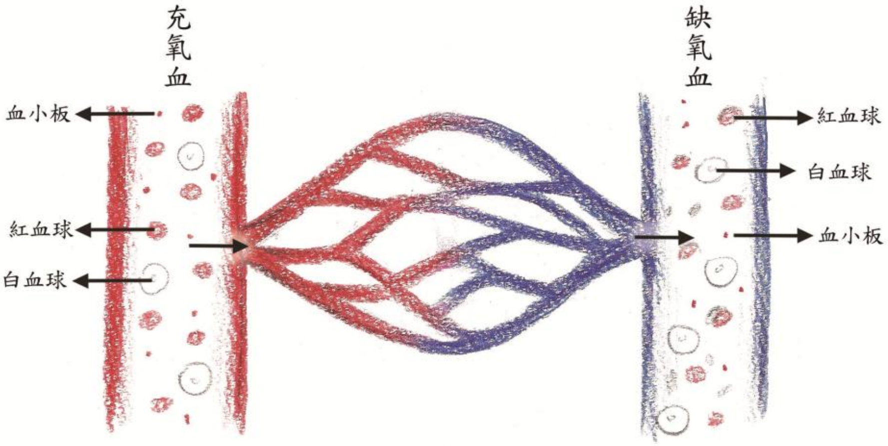
循環系統



D. Prompting questions

心臟、血管與血液



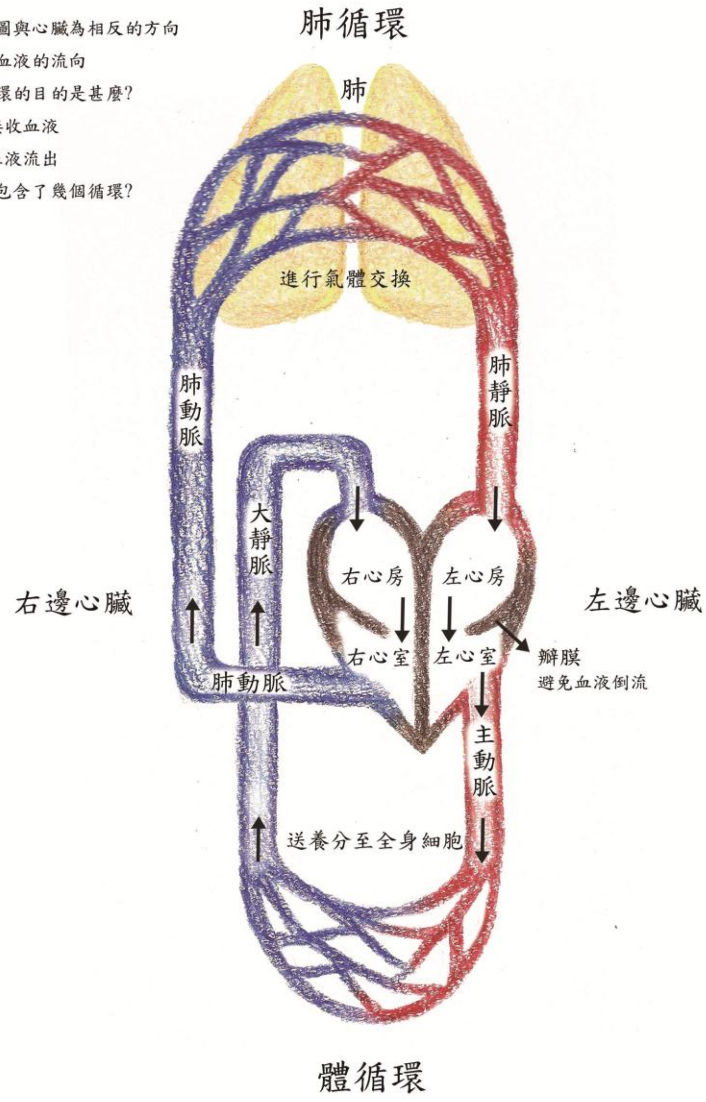


循環系統

充氧血
缺氧血

提示：

1. 請注意圖與心臟為相反的方向
2. 請注意血液的流向
3. 血液循環的目的是甚麼?
4. 心房：接收血液
   心室：血液流出
5. 你的圖包含了幾個循環?



E. Pre-Factual Knowledge Test

1. 心臟由肌肉構成，內有四個腔室，上面為_____________、_____________，下面為_____________、_____________。

2. 血球包含_____________、_____________和_____________三種。

3. 人體的循環可分為_____________循環與_____________循環。

4. 含有許多氧氣的血液稱_____________，氧氣含量低且二氧化碳含量高稱作_____________。

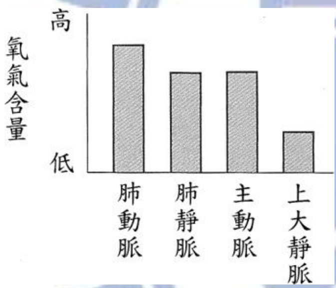
5. _____________的管壁較厚而有彈性，分支的_____________可使血液與組織交換，_____________的管壁較薄且缺乏彈性。

F. Transfer Test

1. 有一種醫療急救設備叫做葉克膜，葉克膜的原理就是把靜脈血引出體外，並以人工肺臟（氧合器）與人工心臟（氣球幫浦）在體外進行循環，而暫時不需要真正心臟和肺臟，以爭取時間。請問真正的心臟和肺臟被氧合器和氣球幫浦取代了甚麼功能？

2. 周結輪的外婆因為生病而無法進食，護士幫她打點滴，你認為是從甚麼血管注射呢?為什麼?

3. 楊澄玲複習循環系統時，推測各血管中的氧氣含量高低，並畫出下面的圖表，但老師說他的圖有錯誤，你認為老師最主要的理由是甚麼?你能幫他改錯嗎?



4. 電影「死亡預告」描述一個虛擬國家，政府可以操縱人民的生命，規定每位兒童進入小學前都要注射「預防接種」，隨機把奈米膠囊注射進入體內，等到成年時，膠囊會在設定的時間破裂而阻斷血管，使得血液無法進入呼吸器官交換氣體而致命。請問奈米膠囊在哪個血管中破裂?請解釋。

5. 小明的腳被鐵片刮傷，留了一些血，為什麼過了不久小明的腳就不再流血了?雖然鐵片上有細菌，但為什麼小明沒有被細菌感染呢?

G. Retention Test

(　　) 1. 請問肺循環最主要的功能是甚麼？(A)進行氣體的交換(B)把養分送至全身(C)抵擋病原體的入侵(D)擠壓血液以進行循環

(　　) 2. 一個完整的人體循環包含哪兩個循環？(A)體循環、胸腔循環(B)心臟循環、肺循環(C)心臟循環、體循環(D)肺循環、體循環

(　　) 3. 心臟跳動的「噗──通」聲代表(A)血管流動的聲音(B)心臟壓縮與舒張時血液衝擊的聲音(C)心與肺在運動時互相碰撞的聲音(D)瓣膜互相碰撞的聲音

(　　) 4. 心臟的分區**不**包含 (A)左心房 (B)後心室 (C)右心室 (D)左心室

(　　) 5. 血液的組成中**不**包含 (A)血小板 (B)一氧化碳 (C)白血球 (D)紅血球

(　　) 6. 請問下列關於循環的敘述何者正確？(A)血液循環的順序是由左心房開始(B)動脈是充氧血(C)血液在右心房進行氣體交換，得到氧氣(D)氧氣含量低、二氧化碳含量高稱作缺氧血

(　　) 7. 有關動脈與靜脈比較，以下何者正確？(A)動脈壁厚度較厚(B)動脈血的氧濃度較大(C)靜脈血是靜止的(D)動脈血是紅色，靜脈血是藍色

(　　) 8. 血液和組織間的物質在何處交換? (A)微血管 (B)主動脈 (C)靜脈 (D)冠狀動脈

(　　) 9. 關於心臟的敘述何者正確？(A)約和一顆籃球一樣大(B)心臟是造成血液循環的原動力，由反覆收縮與放鬆促使全身血液流動的一種幫浦(C)心室是接收血液的地方(D) 心臟有四個腔室，上面為前心室、後心室，下面為前心房、後心房

(　　) 10. 下列人體中細胞及構造功能敘述何者正確？(A)瓣膜可防止血液逆流(B)靜脈負責進行物質交換(C)紅血球只要負責養分輸送(D)心室有較厚的肌肉可以擠壓血液

H. Procedure and instruction of the experiment

實驗流程 with 指導語

	DIPI		DIP / DI		D	
課程教學	實驗介紹、發問卷、填寫同意書	5				
	誠摯感謝同學參與施測，本研究室關於一種學習策略--「生成性繪圖」，想要探討這種筆記的方式對學習者在閱讀科學文章的效果，請先翻至第一頁的同意書來簽名，研究結果可能會發表於期刊，但會確保個位的隱私權，若想得知測驗結果，請填寫您的電子郵件信箱。如果沒有其他問題，請翻至第三頁填寫您的基本資料，並確認填寫完整。有任何問題皆可以舉手發問。					
	暖身練習(瓢蟲)	7				
	重點提示(齒輪的轉動)	8				
	實際操作(細胞學說)	7				
	Feedback 與檢討	8				
			實驗介紹、發問卷、填寫同意書	5	實驗介紹、發問卷、填寫同意書	5
			誠摯感謝同學參與施測，本研究室關於一種學習策略--「生成性繪圖」，想要探討這種筆記的方式對學習者在閱讀科學文章的效果，請先翻至第一頁的同意書來簽名，研究結果可能會發表於期刊，但會確保個位的隱私權，若想得知測驗結果，請填寫您的電子郵件信箱。如果沒有其他問題，請翻至第三頁填寫您的基本資料，並確認填寫完整。有任何問題皆可以舉手發問。			
前測	Pretest	10	Pretest	10	Pretest	10
	接下來我們會使用繪圖的方式來學習「循環系統」，在學習之前，我們想知道您對循環系統的了解程度、以及您的信心程度，請盡量填寫，若有不會的問題可以空著，而感受分析的部分，沒有正確答案，請放心填答。有任何問題皆可以舉手發問。					
Treatment	實驗解說、發問卷	5	實驗解說、發問卷	5	實驗解說、發問卷	5
	現在我們將要進行的是「用畫畫、學科學」的活動，也就是請您邊閱讀關於「循環系統」的文章，並依文章之敘述畫出內容，並以文字輔以敘述來進行學習，只要符合描述事實，圖像本身並沒有標準答案，而是您個人理解的呈現。有任何問題皆可以舉手發問。					
	treatment	20	treatment	20	treatment	35
	給予 prompt	15	給予 prompt	15		
	現在所發下去的是循環系統的示意圖與提示問題，請利用此提示進行對照或修改；但請不要完全將自己的圖完全擦掉。		現在所發下去的是循環系統的示意圖，請利用此提示進行對照或修改；但請不要完全將自己的圖完全擦掉。			
後測	解說、發問卷	5	解說、發問卷	5	解說、發問卷	5
	現在將對剛剛的學習進行測驗，請盡量您所能來作答。					
	後測	35	後測	35	後測	35