Trial of integrated laboratory practice

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The establishment of a self-directed learning attitude is a major goal for current medical students, who definitely need a lifelong learning attitude (4, 7). Problem-based learning (PBL) with a tutor is one such means for students themselves to learn how to learn, how to find problems, and how to find resolutions (6). Such a learning attitude instills medical students with self-directed learning habits. A tutor gives advice, caution, or a hint in the discussion with the student group during the PBL tutorial hour, but does not give the answer. Thus, the students acquire the means to determine the problems in the clinical situation and the best resolutions for the patient among numerous options throughout the group discussion.

Most PBL tutorial hours are followed by class-free time in Japan, and, at the following PBL tutorial hour, the students exchange their resolutions, opinions, or ideas and determine the best one in the group.

Through these processes, students achieve an independent learning style that can be used throughout their life as a learning habit. This is one of the merits of the PBL tutorial system (6, 10). Since physicians are expected from society to be professional, they have to update their medical knowledge all the time, as it grows sharply (11). Our intention for the integrated laboratory practice is the merging of the PBL system and laboratory practice for students. In most medical schools, the instructors provide the students with a laboratory experiment guidebook (3), in which the procedures and, in some cases, the directions and/or nuances of the results are precisely described. Therefore, the students follow the order of the guidance in the laboratory experiment guidebook without thinking critically and deeply about the aim, theory, or technical points by themselves. Such a style for laboratory practice spoils the students; they merely confirm the predicted results written in the guidebook or textbook. Thus, laboratory experiments navigated by well-prepared guidebooks do not require deep thinking on the part of the students. To eliminate such a negative attitude toward basic science and to promote deep thinking habits during college life, we merged the PBL and laboratory practices and perhaps developed a new category, which we term “integrated laboratory practice.”

METHODS

Participants. We mailed an announcement to all medical school personnel to recruit students for the integrated laboratory practice, which is held in August each year at Gifu University for 5–6 consecutive days, since 2005. For each trial, first- to fourth-year students [the course term of Medical School in Japan is 6 yr (5)] from 6 to 10 medical schools have joined. We divided all participants into small groups of ~6–8 students/group. The group members had an almost equal distribution in terms of academic year, sex, and history of biology courses during high school.

Flow chart of the students’ performance. We gave a case sheet to the students groups. One of the cases applied in the trial was as follows:

“A lady (46 yr old) was rescued from a severe train crash into an apartment after the train overran the railway. Although over 100 passengers died immediately, she was rescued 16 h after the crash. The rescue members were surprised to find her in a severe damaged car, and intravenous fluids were started immediately while she was in the confined space. Although she was brought to the hospital, and her family enjoyed the reunion, she died after 4 days in the intensive care unit.”

After vivid discussion, as typically observed with PBL, each group pointed out a specific issue of interest to be clarified by the experiment. The group set up a hypothesis and designed an experimental protocol to investigate the hypothesis, and experiments were then performed. Once the results were obtained, the students and tutors discussed together whether the results support the hypothesis, and,
if not, the students set up another hypothesis that was more compatible with the results (Fig. 1). This procedure is quite similar to that performed by professional researchers. The student groups repeated this cycle several times during the trial to solve the issues they pointed out at the first discussion.

The contents of the case sheet were from recent topics related to medicine. At the first trial, it was from the news, as mentioned above. The students first discussed in the group that the main question was the reason for her death; they further raised questions regarding the function of the kidney in maintaining homeostasis, etc., and then listed experimental possibilities. After several hours of discussion, all groups presented the process and issues of the discussion and debated among the groups. Further group discussion was followed by finalizing the experimental design and starting the experiments. Topics of other years are follows: liver failure (2006), ileus (2007), hemorrhagic shock (2008), and hypothermia (2009). We gave feedback to the students at the formal meeting as well as during an informal discussion/interview.

Staff. As for human resources, we, the authors, discussed with the students as tutors, mainly giving questions. We asked questions during PBL hours as well as during the experimental period. Our questions focused on the mechanism and/or dynamics of the whole body or about the students’ intentions/reasons for raising the ideas for their experiments. These questions stimulated group discussion further, and the goals as well as experimental methods became more concrete and achievable. Although we gave questions, we never gave answers or indications. Instead, we promoted discussion. The guidebook-navigated laboratory practice is rather teacher centered, but the integrated laboratory practice is student centered.

Hardware to perform the experiments. The groups discussed various aspects leading to various experiments. Thus, we had to prepare various kinds of experimental apparatuses. Preparation of numerous types of experimental apparatuses beforehand would be ideal but was impossible in reality. Therefore, we first listened to the students’ ideas and pathophysiological reasons for their experimental design. After this discussion and understanding the students’ ideas, we informed them as to the available hardware at that time and in the institute. Students then started their discussion again and designed a new experimental protocol. These processes forced the students to face reality.

Assessment during the experiments. The authors watched the group activity as well as the students’ personal behavior. The questions during the experiments were often about the aim, goal, results, or pathophysiological reasons, but sometimes about the principles of the methods, such as the accuracy, sensitivity, or limit of the measurements. We individually interviewed the group members during the experiments to know learn the each student’s individual contribution to the group and also to ask whether any participant felt frustrated, because we assumed that there was not enough time for the student to adjust to the new environment.

The students launched a committee for animal ethics and safety before starting the experiments. The main purpose of setting up this committee was that all participants who performed the experiments needed to pay attention to animal ethics as well as safety in complying with the guidelines of the animal experiments of the Physiological Society of Japan (13). We also arbitrarily gave questions to the participants concerning ethical problems as well as safety.

Questionnaire. We gave out questionnaire surveys for evaluation by the students: one survey just after the trial and another survey 1 yr after the trial. For example, the following is a question from the survey just after the trial: What do you think about the idea that students can decide an experimental design in any field of medical sciences through group discussion? The following question is an example of one asked 1 yr after the trial: Are you pleased with the traditional laboratory experiments navigated by a guidebook in your own medical school?

RESULTS

Group discussions for the case. Although students from several medical schools met for the first time at this trial, there were no communication problems inherent to the Japanese traditionally being reticent (1).

The discussions within each group were very active, despite the fact that groups were composed of first- to fourth-year students. For a rather simple question from junior students, the senior students explained in detail, and sometimes they built up the experimental design for the junior students to understand easily.

We asked questions during the group discussion, and every group member could respond to the questions—for example, the aim, the goal, and the anticipated results as well as the methods. It was obvious that the students had a good group discussion because the level of understanding and performing the experiments was high among all members.

Students used a white board to list key words, an abstract of the case sheet, and the hypothesis that they wanted to confirm and/or clarify. They then expanded the discussion to the experimental design based on the hypothesis.

We scheduled breaks for intergroup discussions and had each group present a brief summary. This clarified the characteristics of each group’s experiment, and they tried further to emphasize their group idea and experimental plan.

Planning the experiment. The final plan was established after the presentation to all participants and tutors. The students’ ethics committee then considered the experiments according to whether they met the standards set by the Physiological Society of Japan (13), which are essentially the same as those used in the United States for student experiments (12).

We predicted the students’ thinking process and prepared the necessary chemical reagents and hardware.

The available animals were mice or rats. Students could observe animal behavior and measure urine volume, blood pressure, blood gas, heart rate, respiratory rate, ECG, electromyogram, body temperature, and, in blood and urine samples, electrolytes, glucose, creatinine, pH, etc., which are dependent on the experiments. Other biochemical and histological examinations were also available after the animals had been euthanized.

Performing the experiments. After finalizing the experimental design and getting approval from the committee for animal ethics and safety, the groups started the experiments. As they had discussed extensively, the progress was smooth without any serious trouble. Although some freshmen had never touched mice or rats, they became accustomed to touching and observing the animals during the experiments.

Fig. 1. Flow chart of the students’ performance.
When blood sampling was planned, the supervisor inserted the catheter into the vein or artery. Otherwise, students prepared the electrode for the ECG, thermistor for body temperature, or urinary catheter for the rat bladder.

One student requested a metabolic cage to collect urine from mice, but we told the students that it was not possible to obtain one. Students then discussed and tried to collect urine with a big funnel. However, the mice jumped out of the funnel, so a plastic pet bottle was connected to the funnel. Finally, clear urine was collected into a tube. As the experiments were on renal failure, hematuria was observed later.

Thus, the student groups discussed how to improve the experimental device and also the experimental protocol, such as setting up a control group for comparison.

Assessment. During the experiments, we personally discussed with members individually or with all members of a group and made assessments for the individual and for the group. For the individuals, their participation, performance, and/or skills and response to the question were assessed. This personal interview also aimed to find psychological problems, such as whether any students were frustrated.

Rather than individual performance, our intention was to promote the group to work in collaboration, resulting in good achievement.

Questionnaires. Responses from students just after the experiments showed that they enjoyed the experiment itself and the discussion with participants from other schools and from different academic years. The main impact achieved was that they determined the experimental design by themselves, which was for the first time during their college life (Fig. 2).

One year after the trial, we sent questionnaires asking the degree of satisfaction obtained by the laboratory practice of students’ own school. Only 18% of students were satisfied by the guidebook-navigated laboratory practice experienced after the trial (Fig. 3). More than 20% of the students repeatedly attended the trial held in the succeeding year. Surprisingly, >90% students stated that this trial was useful for the learning of medicine at medical school (Fig. 4).

Essay. All of the participants sent us an essay after they returned home. All of the students said it was a really enjoyable and exciting laboratory practice, which they had never experienced before. And they wanted to share this experience with other students who did not participate.

**DISCUSSION**

The current status of laboratory practice at medical schools in Japan is essentially to maintain the traditional style, where a guidebook is the main instruction for students (3). Faculty members prepare the hardware, chemical reagents, and animals on the laboratory table. Students can follow the protocol in the guidebook without having to think deeply. If the results are not compatible with the guidebook, the faculty claims it to be due to poor technique by the students. As the students have not done the experiment before, the accuracy of measuring some markers in blood or urine would be poor.

Furthermore, due to time limitations, faculty members prepare the tissue extract and/or collect blood for the students to measure. In such a case, students do not need to think about why and how the samples were extracted from the body. This makes it difficult for students to consider the functional interaction of the measurements in the integration of the living whole body.

These guidebook-dependent styles of laboratory practice spoil students because they do not need to think deeply and/or critically. The students have never experienced the achievement and joy of designing and performing an experiment by themselves.

As we nurture educators in basic science for the next generation (9), we need to strongly emphasize to medical students that to design and perform scientific experiments is impressive, attractive, and achievable. In this sense, the new...
integrated laboratory practice may be a unique way to provide this opportunity. If the students experience an integrated laboratory practice once, it may help him/her clarify uncertainties in clinical situations.

Although the PBL system includes several merits, some demerits have also been reported (6, 10). We considered that merits such as group collaboration, which cannot be experienced by the students being alone, outweigh the demerits.

By applying the PBL process to the laboratory practice, the students decided what they wanted to learn, clarify, confirm, or discover. The issues raised by the discussions became the aim of the experiments. The cycle of planning, performing, and evaluating experienced in the integrated laboratory practice is exactly the same as that of professional scientists (2). The students repeated this cycle several times during the trial.

By experiencing this cycle, students felt the achievement, satisfaction, and joy for the experiments. This experience may promote a young doctor to work as a researcher (14).

We emphasized the students’ own thinking process from the case sheet to the results, and not results themselves. Engagement of the PBL process with laboratory practice has not been reported in medical education, to the best of our knowledge.

We have organized the medical educators’ workshop to develop the curriculum for this integrated laboratory practice to large classes and are still seeking for a final application to a large class (8).

DISCLOSURES

No conflicts of interest, financial or otherwise, are declared by the author(s).

REFERENCES


