Chapter

Development of Support System Modeled on Robot Suit HAL for Personalized Education and Learning

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Abstract

The purpose of this paper is to maintain quality education for each student who has her/his own differentiation and needs. To achieve it, we have developed our support system for education and learning. We have examined this support system, whether it improved or did not improve the performance of 98 students in 2015, compared with that in 2014. The results have shown to be more significant than those of the previous year. Moreover, we have observed that students' behavior toward projects have been becoming greater autonomy and positive attitude in practical class. From those results, we might be able to say that this support system works effectively in personalized education and learning (PEL) by using big data processing.

Keywords: personalized education and learning support system (PELS), feedforward control, feedback control, interactive communication, behavior patterns, big data processing

1. Introduction

In this decade, personalized education and learning has become noticeable as an educational reform by using ICT in many countries [1, 2]. Personalized education and learning are instructions designed for students, meeting their needs and matching their traits, such as their learning styles and abilities [3]. Their needs and traits are different from each other, which is so-called differentiation. It is considered that the differentiation is mainly affected by personality, cognitive style, and so on [4]. Instructors will have to teach students individually, optimizing their needs and traits [5].

There have been reported studies on personalized education and learning with computer-based e-learning system collaboratively with artificial neural network [6, 7]. Recently, however, blended learning, which incorporates both face-to-face learning and e-learning by using ICT [8–11], has begun to be reconsidered on collaborative learning from social constructivism approach [12–15].

It means, however, that instructors do not always teach each student separately but in groups at the same time. It seems hard and complicated for instructors to match with each student's trait in group. Instructors will also have to design instructions in detail so that they can optimize members in group by analyzing students' traits [16, 17].

When they analyze students' differentiation of their traits, instructors will have to prepare students' various data for analysis [18, 19]. If ICT is used in class, it would be easier for instructors to collect data of students' various kinds of data; for example, when student responds to subjects given or assigned, instructors would be able to collect students' data in real time [20, 21].

How responses have been related to subjects, for example, what students have judged and decided, or which they have chosen their responses, will be recorded and accumulated by using ICT. Instructors will be able to understand students' psychological state and predict their learning behavior from their various kinds of data, not only in class but also before and after classes. In this viewpoint, those various data, which are collected and analyzed for educational aims, will be called big data processing [22–26].

On the other hand, however, it might have been becoming more difficult for instructors because nonverbal communication must be limited when they use computers in class. It means that there might be fewer information for instructors to obtain data for analysis of learners' psychological state by observing their behavior from outside while they are using computers in class, especially, for the first year students. Along with those reasons, it seems more difficult for instructors and students to keep educational quality in collaborative learning than before without big data processing.

To solve those problems, in our research, we are proposing some methods of personalized education and learning from the systems approach in the field of educational technology [27]. Practically, we have developed our support system for personalized education and learning (PELS) [19]. This system is modeled on Robot Suit Hybrid Assistive Limb (HAL) in cybernetics theory. As an examination of this support system, we will show a practical method of education with Start-Plan-Do-Check-Act (SPDCA) cycle [28, 29].

2. Concept of system

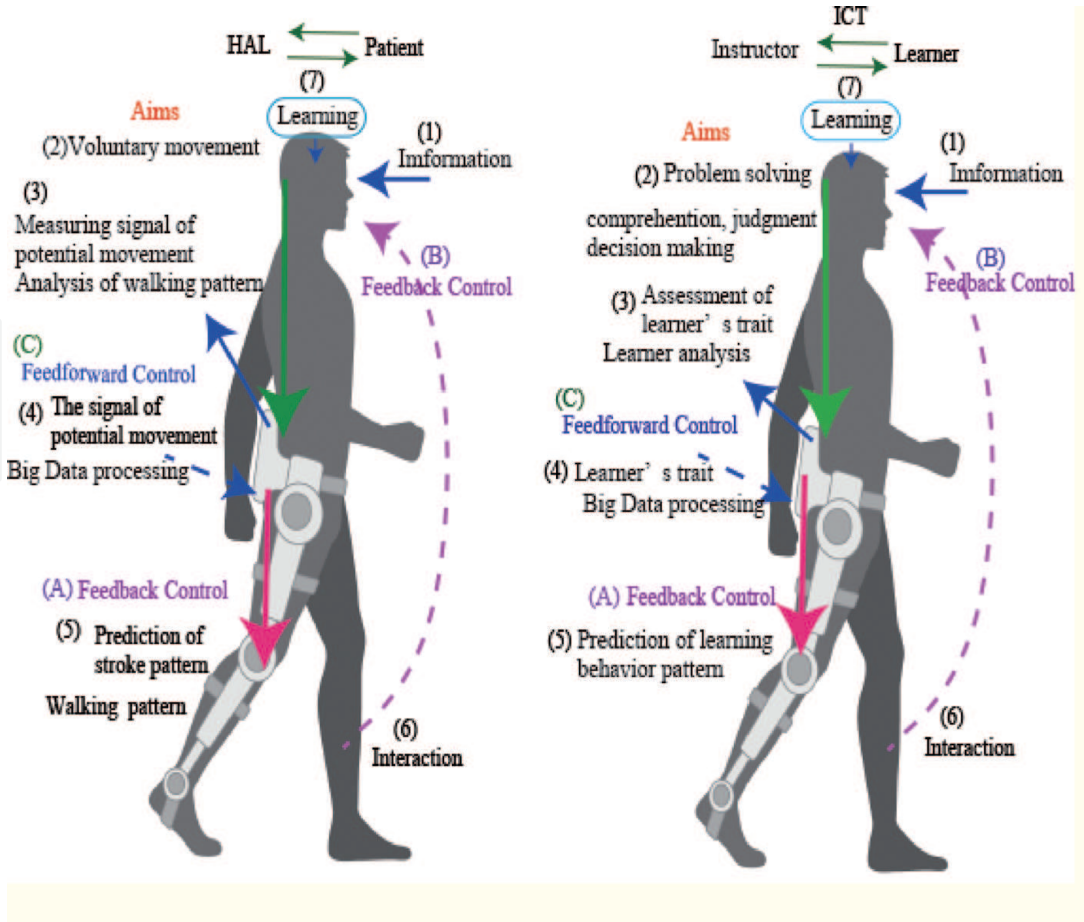
2.1 Structural elements

In the field of educational technology, systems are combined with interdisciplinary approaches [23], especially based on social constructivism. For example, educational system, biological system, and engineering system are elements of a social system. Because they are functioning interactively with each other, their relationship must be strong.

Cybernetics claims that biology and mechanical device are mutual theories, concerning communication and control. Along with unification of both systems, it is insisted that the new combination of science and technology becomes another development. Sankai has proposed the cybernetics theory [30–33], which is a technological concept of the support system by interactive communication between machine and human or brain. This cybernetics theory is combined with cybernetics, mechatronics, and informatics (**Figure 1**, left (1)) [34]. And Sankai has developed Robot Suit HAL. From those interdisciplinary viewpoints, in the field of educational technology, there are a lot of mutual concepts of our support system. Then we have developed our support system theory, modeled on Robot Suit HAL [35].

2.2 Schematic diagram

Our concept of PELS modeled on HAL is an interactive robot suit that enables people to expand human ability. HAL has been developed for patients who have difficulties to walk, assisting their motion and instructing between the doctor



	Item	HAL⇄ Patient	Instructor(ICT)⇄Leaner
(A)	Feedback Control	HAL → Patient	Instructor(ICT) →Leaner
(B)	Feedback Control	Patient(Body)→Patient(Brain)	Learner(front lobe)→Leaner(hippocampus)
(C)	Feedforward Control	Measurement Instrument → HAL	Psychological Measurement →Instructor)
(1)	Information	Situation	Language
(2)	Aims	Voluntary Movement	Problem-solving, Judgement, Decision Making
(3)	Measurement, Analysis	Walking Pattern	Learning Behavior Pattern
(4)	Big Data Processing	Signal of Electronic Potential Motion	Learner's Trait, Characteristic
(5)	Estimate , Predict	Walking Pattern	Learning Behavior Pattern
(6)	Interaction	HAL⇄ Patient	Instructor(ICT)⇄Learner
(7)	Learning	Method of Walking, Rehabilitation	Method of Information Processing, Means and comprehension

Figure 1.
Concept of personalized education and learning support system (PELS) (revised Figure 1 in Tsujioka [36]).

and patient in rehabilitation [37–40]. HAL is composed of cybernetics voluntary control (CVC) (**Figure 1**, left (2)), cybernetics autonomous control (CAC) (**Figure 1**, left (3)), and cybernetics impedance control (CIC) (**Figure 1**, left (4)) [34] without heaviness. The wearer becomes aware of physical information by CIC of HAL. And she/he is able to obtain walking motions based on voluntary movement [41].

This system supports patients for correct walking patterns without errors (**Figure 1**, left (5)). It is accomplished by wearing HAL and comparing multiple brain areas and muscle-joint movements in real time (**Figure 1**, left (6)). Because HAL makes the brain active and the motor phenomena to reiterate correctly, its neural plasticity forward movement program is expected to improve learning effects for patients (**Figure 1**, left (7)). It is based on Sankai's hypothesis of interactive biofeedback [38, 41].

HAL consists of frames, actuators, sensors, and the main controller [42, 43], big data processing, for analysis. It is important for patients because they have different troubles with walking. Therefore, the measuring system of sensors gathers each patient's voluntary movement so that they can help patients.

HAL has two kinds of control systems, feedforward and feedback. And the main controller has been stored various data [39], for example, walking behavior and muscle movements of the unaffected leg of patients (**Figure 1**, left (C) feedforward control). Those data added signals of patients' voluntary movement from the sensing system in real time and will analyze and predict optimum walking patterns so that patients would be able to walk smoothly (**Figure 1**, left (A) feedback control). Those ideal patterns of walking will also give feedback to patients while they are getting their rehabilitation, so that it can help patients walk independently with both legs (**Figure 1**, left (B) feedback control) [34].

In the personalized education and learning support system [36] case, it has been storing various data, for example, student's traits, needs, and so on (big data processing). Instructors would be able to analyze students' data and predict students' behavior (**Figure 1**, right (C) feedforward control). And they will be able to design their instructions to meet with students' differentiation and needs, like optimized grouping members for project teams (**Figure 1**, right (A) feedback control). Through learning with those team members and matching instructions with their needs or requirements, students might also be able to know how to make collaborative relationship with each other (**Figure 1**, right (B) feedback control) [36].

2.3 Element of the system and relationship

The table in **Figure 1** [36] shows how the elements of the educational and learning support system are related to HAL. In the case of PELS system, however, language information (**Figure 1**, right (1)) should be more important for interactive communication among students in teams (**Figure 1**, right (6)). In this point, the main controller would store more various kinds of data, for example, students' performance records, differentiation, attitude, and so on, in class (**Figure 1**, right (4)).

In education, learners obtain information from instructors at first (**Figure 1**, right (1)). In this case, communication media is mainly language. After they have obtained language information about the projects, learners begin to solve problems, which are given or assigned, by judging or deciding from those information (**Figure 1**, right (2)). Instructors should predict how learners would like to make their decision (**Figure 1**, right (3)) and how they would behave (**Figure 1**, right (4)), by analyzing learners' data (**Figure 1**, right (5)), which have been collected beforehand. Because instructors need to give their feedback to students smoothly, depending on learners' traits with interactive communication, like walking with two legs normally (**Figure 1**, right (6)).

Instructors will have to decide the members of each team by some kinds of rules, so that learners will be able to communicate with each other smoothly while they are addressing problems for their projects. When learners would like to exchange their opinions or information to solve problems for given subjects, learners must be required to have some social skills (**Figure 1**, right (7)).

2.4 Hypothesis

Considering the transition of learning, it is predicted that it is more difficult for instructors to understand learners in the case of (2) or (3) than (1) in **Figure 2**. And also, in the case of learning with social media system collaboratively (4) [19],

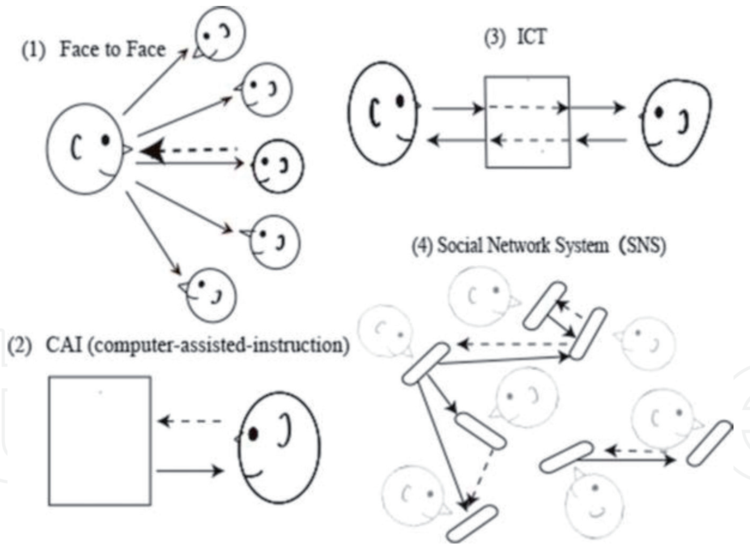


Figure 2.
Transition of education and learning configuration.

it might have been more difficult to communicate interactively, not only between instructors and learners but also among learners.

This means that it might not be easy for instructors to design instructions for learners without their learning traits which includes their learning style, personality, information processing traits, and so on (so-called big data processing), especially for new students.

The big data processing system (**Figure 3**) [19] provides learners' information beforehand with the measuring system and the assessment output system of the data analysis system so that instructors can plan their class.

Then, we have formulated hypotheses suggested by PELS model:

a. Feedforward control system (**Figure 1** (C), **Figure 4**(11)) [19] will enable instructors to predict their students' behavior (**Figure 1** (A), **Figure 4** (7)).

b. It will bring mutual understanding between students and instructors or students and students by interactive communication (**Figure 1** (6)). It might

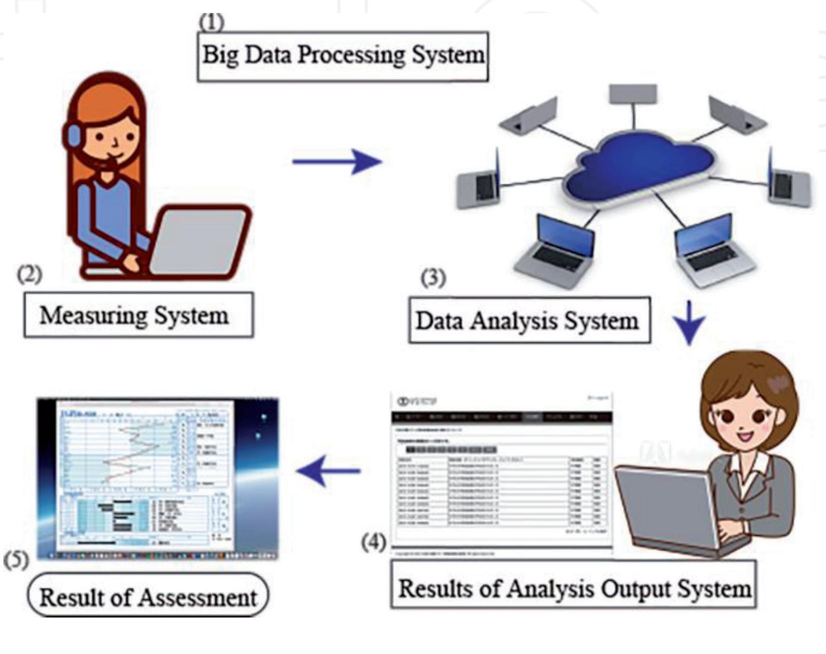


Figure 3.
Concept of big data processing [19].

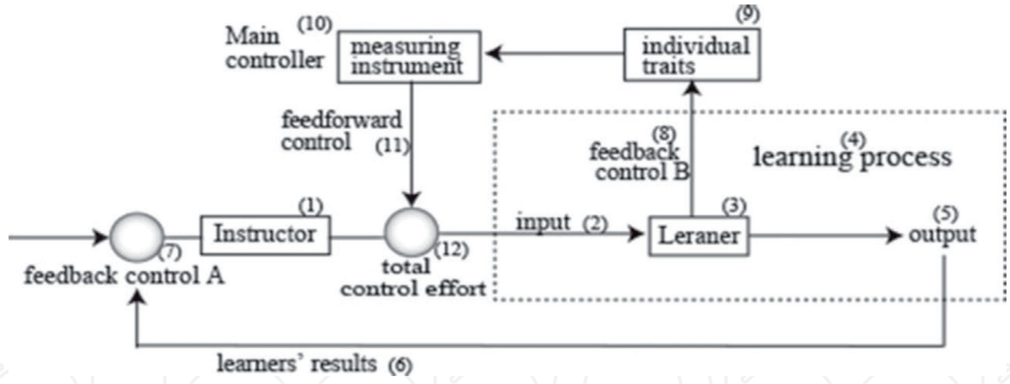


Figure 4.
Model of personalized education and learning support system [19].

help students to become independent and positive in class. Consequently, it will have effects on students' performance and attitude in class.

As those hypotheses are tested based on this PDLS model, we have designed the practical experiment along with SPCDA method [44].

3. Design

According to the theory, we have carried out a practical experiment of the PELS system to prove its effects. By using the PELS system, we will evaluate the method of education so that they might be able to improve their instruction to students, approached by SPDCA cycle (**Figure 5**, SPDCA ①-⑦) [29] based on PELS model (**Figures 1** and **2**) in order to examine the learning effect by our support system.

When we designed this plan, we also have discussed on how to examine this PELS system or whether it might work practically well, or not. At first, we had heard from a person who was participating in practical examination about what were the problems in her class, so that we can find their solution. She was a chief instructor in practical nursing class at the nursing department of the university. Her students will be eligible for the national examination after graduation to obtain qualifications of a nurse. In this reason, they are required to accumulate credits

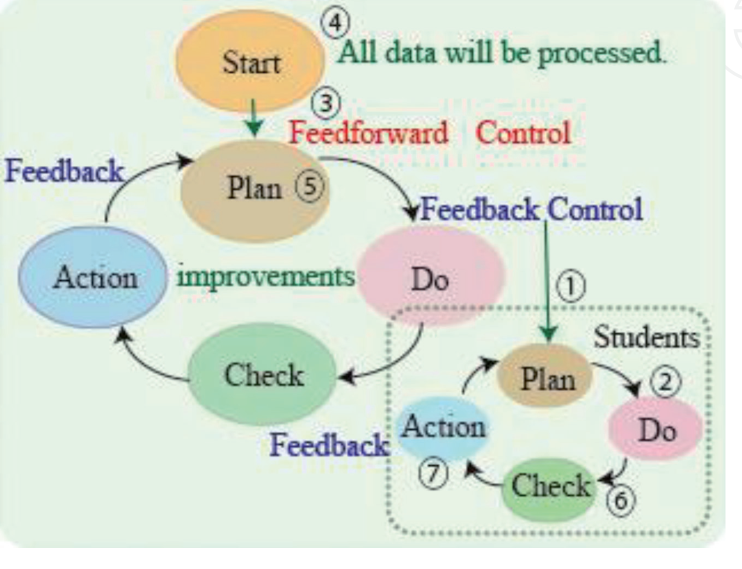


Figure 5.
The method of testing hypotheses (revised Figure 10.5 in Dannelle [44]).

toward their degrees which they will earn by standard evaluation strictly. The main problems which she has emphasized were as follows:

- A lot of students have dropped out.
- Records of students' performance have been declining.

Her aim is for students to obtain nursing concept in the first term, changing their views from general to expert. However, she thinks that it would be difficult for students to begin to be aware of the nursing expert concept. She believes that it might be related to the high ratio of leaving their job or dropping out while they are students.

Secondly, after hearing about the present situation from her, we have analyzed the problems in her class so that we could find the solution. Through finding out the reason why those problems had happened to students, we have to decide the best. Another instructor who worked at the same department said that a lot of students have been late in class and hesitated to join or start the practice for their project with team members (**Table 1**, (a) and (b) in 2014). Those phenomena might be the same problems which were mentioned by both instructors.

Finally, from those viewpoints, we became to have research questions: why students cannot study enthusiastically or what is happening to the students. Those

Points of Examination		2014	2015
(a)	Standby	a few students	most of all students
(b)	Warm up	The class has always been late about 10 minutes.	The classes has always started in time.
(c)	Attitude to the Problem Solving for Task	It was difficult to cope with a problem for practices.	After the instruction, students have began to talk with each other in order to address a problem and tackle with practice very smoothly.
(d)	Exchange of Views	There has not happened in some teams to interact with each other smoothly.	All teams took interactive communication smoothly for an exchange of their views.
(e)	Participation in Class	Some students were not able to participate in class.	Almost all students have participated in class independently.
(f)	Instructors' Reflection	No particular support was conducted. They looked for students from a subjectivity point of view.	Instructors reported that they have predicted learning behavior of students who were concerned with their attitude, referring to the consultation of psychological assessments. Instructors have also reported that they have been able to view student behavior objectively.
(g)	Grouping (each team is four members, 25 teams)	In class, the grouping of team members was organized by the order of students' ID number. Teams were not divided into groups by each instructors. In pilot experiment, the chief instructor decided to put students into groups optimizing by her experiences.	The chief instructor decided the grouping of team members, optimizing by her experiences based of assessments of psychological testing and other data. She also divided teams into five groups by each instructor's experience and the condition of an employment .

Table 1.
Comparison of attitudes toward class between 2014 and 2015.

problems should be analyzed for us to understand their present situation. We have also heard from the other instructors about the problems in 2014 (**Table 1** (c)–(e)). Bringing their opinions altogether, it is considered that their learning has been organized or formed by interactive communication between learner-learner or learner-instructor. We predicted that if their communications are exchanged smoothly with each other, those problems will be solved.

4. Solution

After we have heard from instructors about their problems in class, we have designed the practical SPDCA cycle (**Figure 2**) with PELS system based on the theory of HAL model.

1. **The first cycle** (pilot experiment)

    a. Plan

    - Planning for supplementary lessons of practical nursing class.
    - Students are freshmen and sophomores.
    - They participate in class voluntary for 3 months.

    b. Do

    - The chief instructor decides to put students into teams through her experience.
    - They are assigned to complete presentation of their projects with team members.

    c. Check

    - Evaluation of each team's assignment.
    - Reporting about each students' attitude or behavior in the team.

    d. Action

    - After they have finished their presentation, students take psychological testing.
    - The instructor will be able to predict which teams might succeed and which might not, referring to the results of her evaluation and observation of students' collaborative work in the team.
    - We asked her to compare her reflection with the evaluation of psychological testing so that she might become aware of the method of grouping.

2. **The second cycle** (a practical experiment)

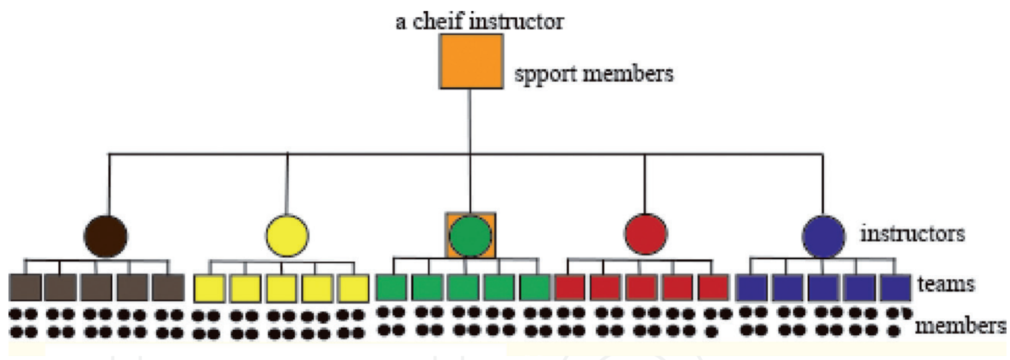


Figure 6.
The method of teaming [19].

a. Start: Data gathering for freshmen in 2015 (feedforward to Plan)

- Psychological testing (personality measurement).
- Questionnaire (ask about students' needs, requirements).
- Students' records in the previous year (in 2014).

b. Plan

- Asking the chief instructor to plan her first cycle reflection of the pilot experiment in order to decide members of teams [10] and form teams dividing them into five instructors (**Figure 6**).
- Making plan to collect data for evaluation of this support system.

c. *Do*: Explaining about the aims of PELS (feedforward to students) and gathering data (feedback to Check)

- Reports, attendance, and attitude (participant observation).
- High-stakes assessments.
- Examination of first term test for practical performances.
- Low-stakes assessments: pre- and post-quiz about basic nursing special concepts.

d. *Check:* Analysis and assessment of students' performance through data gathered in previous sections, Start, Plan, and Do

e. *Action*: Reflecting the classes by analyzing the result of students' performance and participant observation

5. Results

5.1 Pilot

At first, we have asked the chief instructor to reflect grouping of team members based on her experience, comparing with assessment of psychological testing and

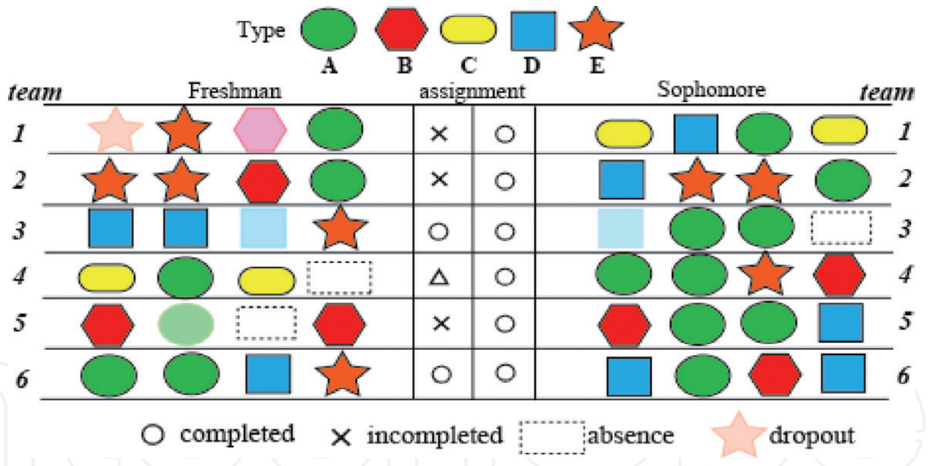


Figure 7.
The results of teams put together through the experience of instructors [19].

the other students' data for participants in the pilot experiment. We also have asked her to report them and explained her why some teams have not completed their presentation for their projects and the others have done well from the view points of matching members for each team.

The results of the pilot experiment are shown in **Figure 7**.

- Fifty-one students participated voluntarily (female; freshmen, 29; sophomore, 22).
- The period was from November in 2014 to January in 2015 (about 3 months).
- Fifteen groups were divided, not by assessment of psychological testing, but by instructor's experience (nine teams for freshmen, six teams for sophomores (**Figure 7**) [19].
- Two of nine teams have completed their presentation for freshmen, and four of nine teams dropped out. All teams of sophomores have completed and succeeded their presentation.

5.2 Examinations

We have done a practical examination for our PELS system along with the design of SPDCA cycle.

3. Practical experiments

   a. Participants: Ninety-eight freshmen students have participated in the practical examination.

   b. Period: The period was from April to August in 2015 (about 5 months).

   c. The data: All students' records were gathered (the first term test as high-stakes assessments and pre- and post-quiz as low-stakes assessment) the ratio of attendance and the record of the process how members have done their assignments interactively through text message, reports, and video which were recorded by the learning management system (LMS).

   d. Students' records of the previous year: the data of 97 freshmen's records in 2014 as high-stakes assessment.

e. Observation: Instructors report, and the participant observation was also gathered (**Table 1**).

5.3 Comparisons

1. The results of t-test probability (**Table 3**): There are comparisons of t-test results of probability between pre- and post-quiz for the low-stakes assessments, practical tests for the high-stakes assessments (**Table 2**), and the percentage of attendance between 2014 and 2015.

    a. Low-stakes assessment: The results of post-quiz about the special concept for nursing have become significantly higher than those of pre-quiz. The average point of the post-quiz was about 4.25 higher from 1.91 to 6.25 (total 10 points) (**Table 3**).

    b. High-stakes assessment: The result of practical assessments is significantly higher in 2015 than those in 2014. The average point was about 25 points higher from 58.94 to 83.95 (for a total of 100 points) (**Table 2**).

    c. Attendance: The result of the attendance percentage is higher in 2015 than that in 2014. The average of the potion of perfect attendance for the first semester in 2015 became higher from 97.3% in 2014 to 99.5%.

2. Low-stakes assessment (**Figure 10**): The concepts of nursing development: **Figure 8** shows the comparison of total points for each team between pre-and post-quiz in practical nursing class. The results of most teams were better in pro tests than pretest. The members of team 4 and 14 have declined their performance.

3. High-stakes assessment (**Figure 9**): The figure shows the distribution of students' performance records for practical assessment tests, comparing the results of the pre-term between 2014 and 2015. The range of 51–60 points is the highest in 2014 and those of 91–100 points in 2015. In the case of students whose performance are evaluated under 60 points, they might fail in the practical subject and drop out, except taking an examination again and acquiring credits.

Practical Assessment (100 points)							
Year	*N*	$\overline{X}$	*SD*	*df*	*F*	*test*	
2014	97	58.9	12.4	193	198.8***	0.000	***
2015	98	84.0	12.4				

Table 2.
Significant differences of high-stakes assessment.

Low Stakes Assessment		*N*	$\overline{X}$	*S.D.*	T-value	*df*	*t*- Test	
Quiz (10 points)	Pre	97	1.91	2.70	-11.6	96	0.000	***
	Post	97	6.25	3.19				

Table 3.
Significant differences of low-stakes assessment.

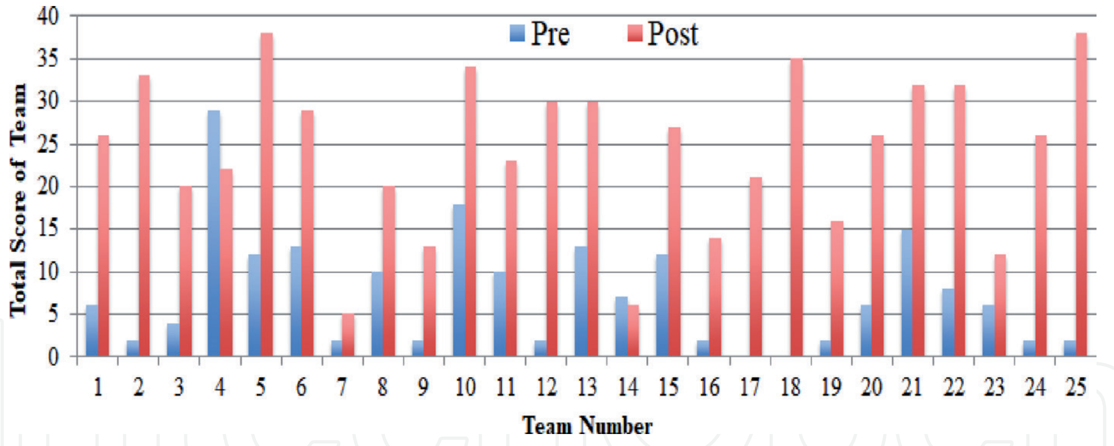


Figure 8.
Comparison of scores between pre- and post-quiz in practical experiment.

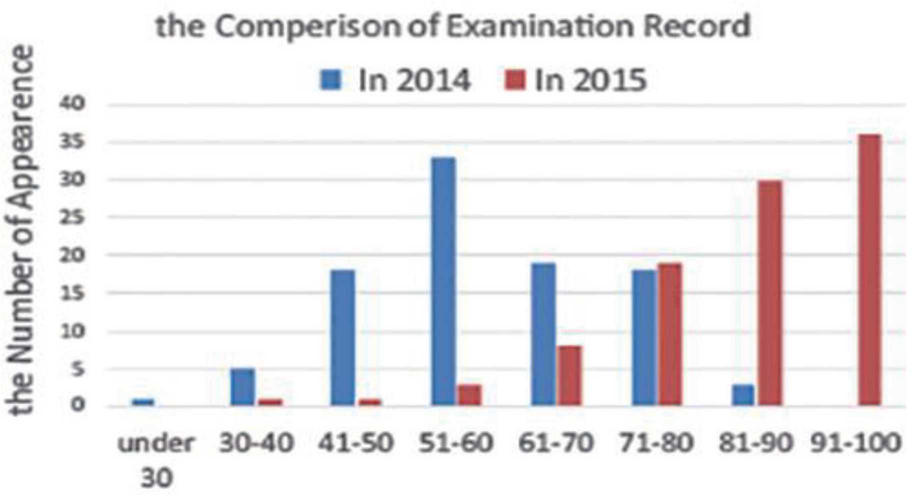


Figure 9.
Distribution of records comparing high-stakes assessment between 2014 and 2015.

4. The ratio of perfect attendance comparing between 2014 and 2015 (**Figure 10**): The figure shows that 96% of students had attended practical nursing classes perfectly in 2015, which is higher when compared to 53% in 2014.

5. Observation (instructors) (**Table 2**, (a)–(e)): The comparison of instructors' observation between 2014 and 2015: From their assessments of observation, students' performance has become better in 2015 than in 2014. The results are strongly related to other assessments;, for example, the situation of standby class is related to perfect attendance percentage.

6. Observation (instructors' reflection in class) (**Table 2**, (f)): Instructors have changed their views and attitude toward students, from subjective to objective.

7. Observation (supporters' participant observation in class) (**Table 2**, (g)): This is the supporters' reports on how the method of groping or teaming has been changed from 2014 to 2015. This method was consulted by supporters for instructors and students as the one element of the PELS system.

8. All results of observation reports from instructors (a)–(e) (**Table 1**) shows that the system has worked well with interactive communication among students which had been observed at role-playing in class (**Figure 11**).

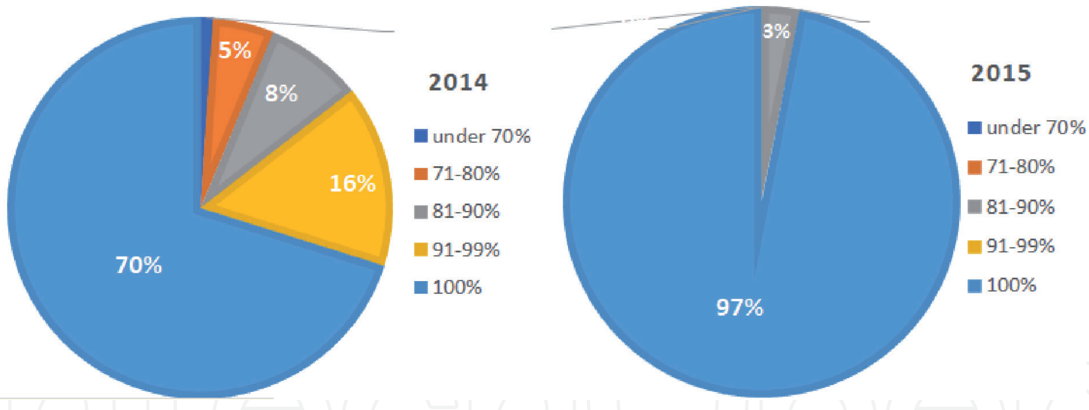


Figure 10.
Comparison of attendance ratio between 2014 and 2015 of the first semester.

Figure 11.
Participant observation for role-playing in class [19].

6. Discussion

6.1 Examination of PELA

The results of examination for the PELS system were clear evidences that have shown fair improvement in students' performance and attitude. It might be able to say that the system has supported effectively for both instructors and students.

However, we will have to look at the reason why students have been hesitant in joining practices in class before the support had been conducted. Almost all students have begun to study about nursing enthusiastically and independently after the system has been provided. We might not be able to continue using this support system successfully or fruitfully, without finding out the reason why the system had an effect on nursing personalized education and learning [45, 46].

6.2 Examination of pre- and post-quiz

Pre- and posttests in class were the same tasks given to students (**Figure 8**, **Table 3**). Students were required to discuss the problems about the environment in a sickroom which was shown by a picture. This test measures how the students' concept has come to change, concerning their specialty in nursing. From the results, we have found that there has been a differentiation among teams, depending on students' traits and social abilities [47, 48]. Their interactive communication must have had an effect on their learning which might have changed their concepts for collaborative working. We will have to find out the reasons why the performance of some teams has significantly improved.

6.3 Observation

From this observation report, we can see that students had paid their big efforts to improve their performance in 2015 (**Table 2**). In the last column, instructors have reflected on their attitude toward students. We will need to consider about what is the reason for which instructors have been changed their view of teaching objectively and why they have become to change their attitude to students in class [49]. One of the reasons might have been the feedforward control system that enabled instructors to obtain students' data when they designed their instructions, depending on their personality, needs, and so on (feedforward control) (hypotheses (a)). They tried to analyze students' data in order to understand their differentiation. It means that the instructors began to see individual students and they might have obtained reliabilities from students (feedback control). I think this has an important meaning for personalized education and learning. We can say that it has brought them mutual understanding and interactive communication between not only instructors and students but also between students and students. Consequently, students might have shown their ability independently and positively to us (feedback control) (hypotheses (b)).

6.4 The relation to the theory of HAL

What is of most importance in the theory should be discussed. If students or instructors cannot find their own methods how they learn for changing their views, their improvement would not be continued (SPDCA cycle: **Figure 5** related to **Figures 1** and **4**). Instructor might have acquired how they can make an accurate forecast their students' behavior (Feedforward Control). According to it, they have planned their instruction for class and combined appropriate grouping and teaming. In practical class, it was considered that instructors have guided student adequately depending on their individual traits (Feedback Control A). Consequently, it might be observed interactive communication not only among students but also between instructors and students. Moreover, students' performance might have significantly improved with their autonomous and activity (Feedback Control B).

7. Conclusions

The purpose of this chapter is to propose the educational reform [3] so that we can maintain quality education. The collaborative learning with ICT might have been considered the best method to realize it, but there were some reported problems, especially regarding interactive communication (**Figure 2**) [13].

Along with the educational reform and personalized education and learning (PEL) [5], we have introduced cybernetics theory of HAL into our model of PELS, which consists two kinds of feedback control, feedforward control and main controller (**Figure 1**) [36].

Various data of learners' individual traits would be gathered and analyzed in the main controller (**Figure 3**). The results of those assessments would be informed to instructors before designing class (feedforward control) (**Figure 4**) [41]. Learners would be able to learn how to interact with others autonomously (feedback control B) (**Figure 1**).

The SPCDA cycle was applied (**Figure 5**) for experiments in nursing science class with problem solving so that we can prove whether the model of PELS is effective or not for collaborative learning. The result of the first cycle (pilot experiment) was shown in **Figure 7**. The instructors have obtained the rule for combination of team members (feedback control A) (**Figure 7**).

In the second cycle of SPDCK (practical experiment in 2015) they have decided how to combine members for optimized each team from students' traits which have been assessed by big data processing system (feedforward control) (**Figures 1** and **3**) [19]. The results of learning effects were shown by comparisons (**Tables 1** and **3**). Both low-stakes assessment (**Figure 8**) and high-stakes assessment (**Figure 9**) have been shown to be more significant. And moreover, the comparison of attendance ratio between 2014 and 2015 was shown to be more significant (**Figure 10**).

It is considered that the learning effects were shown significantly getting better by PEPS. It is considered the reports of participant observations, which were compared with students' attitude in class, matched with the results of assessments.

In conclusion, we have shown that the PELS works effectively with interactive communication between instructor and learner and learner and learner. Consequently, learners have become stronger to study independently and positively through personalized education and learning. This means that this system was useful and helpful for instructors by using big data processing and analysis [22] so that we can maintain quality education.

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